TJ163.2
W51

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

RECEIVED
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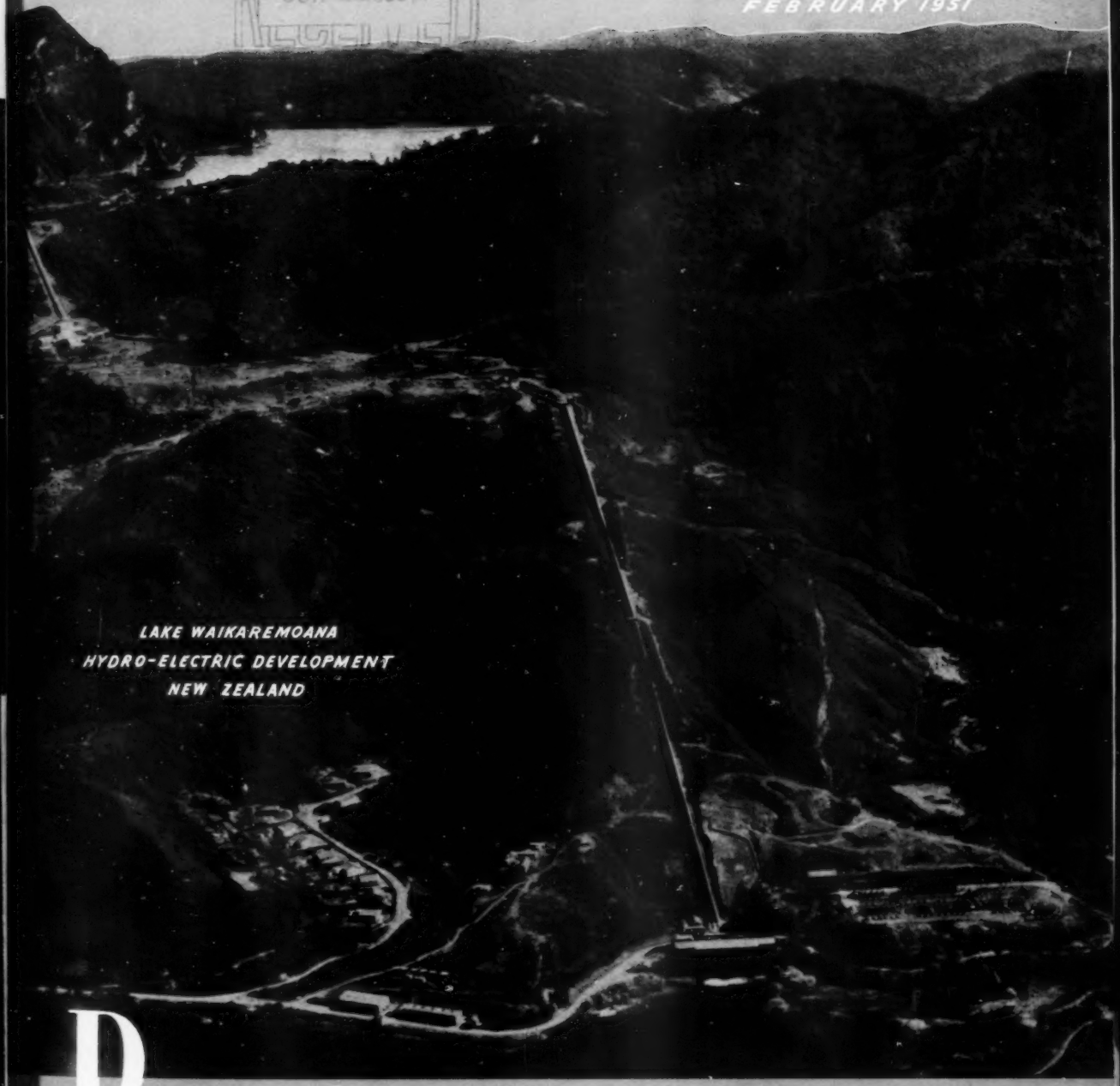
FEBRUARY 1951



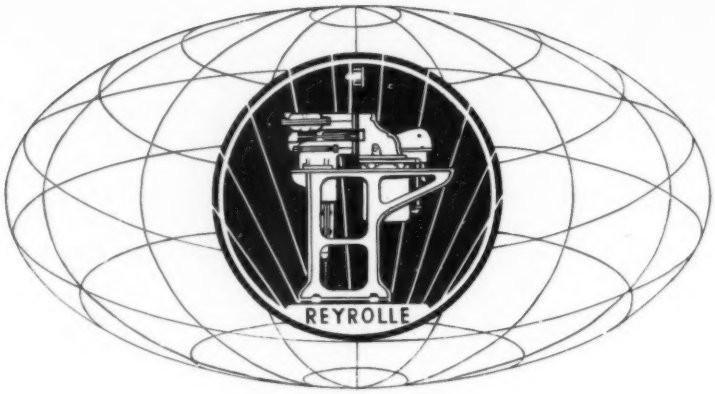
LAKE WAIKAREMOANA
HYDRO-ELECTRIC DEVELOPMENT
NEW ZEALAND

Boving

The upper station - Kaitawa - has two 21,000 BHP Boving Francis Turbines; the lower station - Tuai - one Boving Francis Turbine of 28,000 BHP.

& COMPANY LIMITED WATER POWER ENGINEERS

LONDON : AUSTRALIA : NEW ZEALAND : INDIA : PAKISTAN



As the largest specialist switchgear-manufacturer in the world, we are proud of our record, which goes back more than sixty years to 1886

We have comprehensive manufacturing and testing facilities wholly devoted to the wide range of products required for the control of electricity

Reyrolle

HEBBURN · CO. DURHAM · ENGLAND

'ENGLISH ELECTRIC'

hydro-electric power

130 Megawatts from Sloy

The years of planning and labour which have gone to the realisation of the Loch Sloy scheme have had one fundamental object in view—the harnessing of Glen Sloy's 120-inch annual rainfall to drive four 'English Electric' hydro-electric generators delivering 130,000 kW of electric power.

The four 45,500 h.p. turbines with Francis-type runners are controlled by cylindrical balanced valves from a gross head of 920 ft. The 32,500 kW main alternators are coupled through 'English Electric' power transformers and oil-break switchgear to the grid at a pressure of 132 kV.

'English Electric' have played a large part in the development of Scotland's hydro-electric resources since the Galloway and Grampian projects, and are building equipment for several of the schemes which the coming years will see in being.

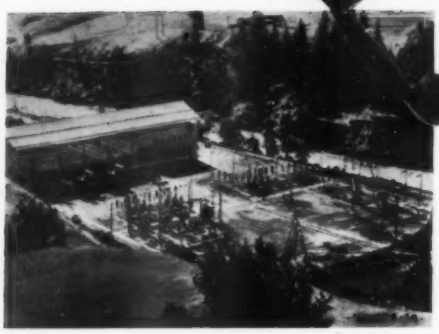
THE ENGLISH ELECTRIC COMPANY LIMITED

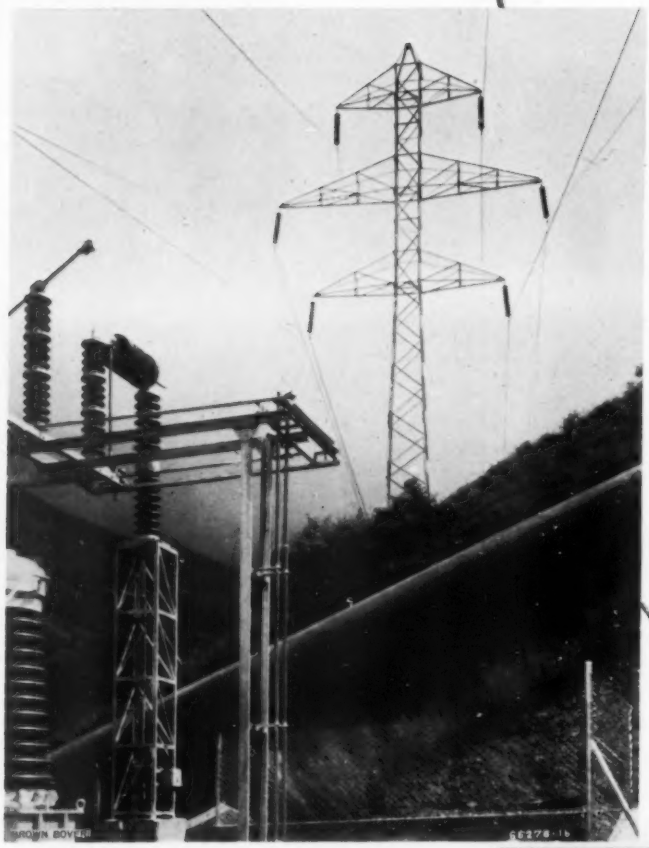
QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Hydraulic Department, Stafford

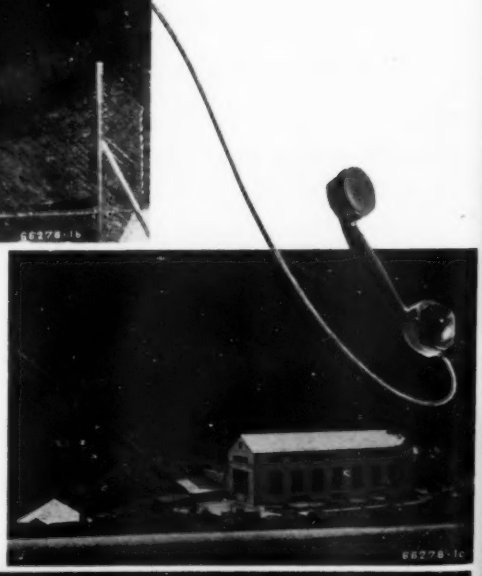
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL

Power-Line Carrier Telephony





Coupling equipment of a carrier telephony transmission at the Mörel power station (Switzerland) 500-A double-wave trap and associated coupling capacitor mounted on a special frame in the outdoor switching station. This carrier link, superimposed on the 150-kV transmission line over the Nufenen pass, permits telephone communication between the Mörel and Lucendro power stations.



Our range of manufactures includes:

Radio equipment for stationary and mobile applications / Radio-relay equipment / Broadcasting and radiotelegraphy transmitters / Electronic generators for industrial purposes / Transmitting and rectifier tubes / Remote supervisory equipment

BROWN BOVERI

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

LEFFEL

PRODUCTION INSURES

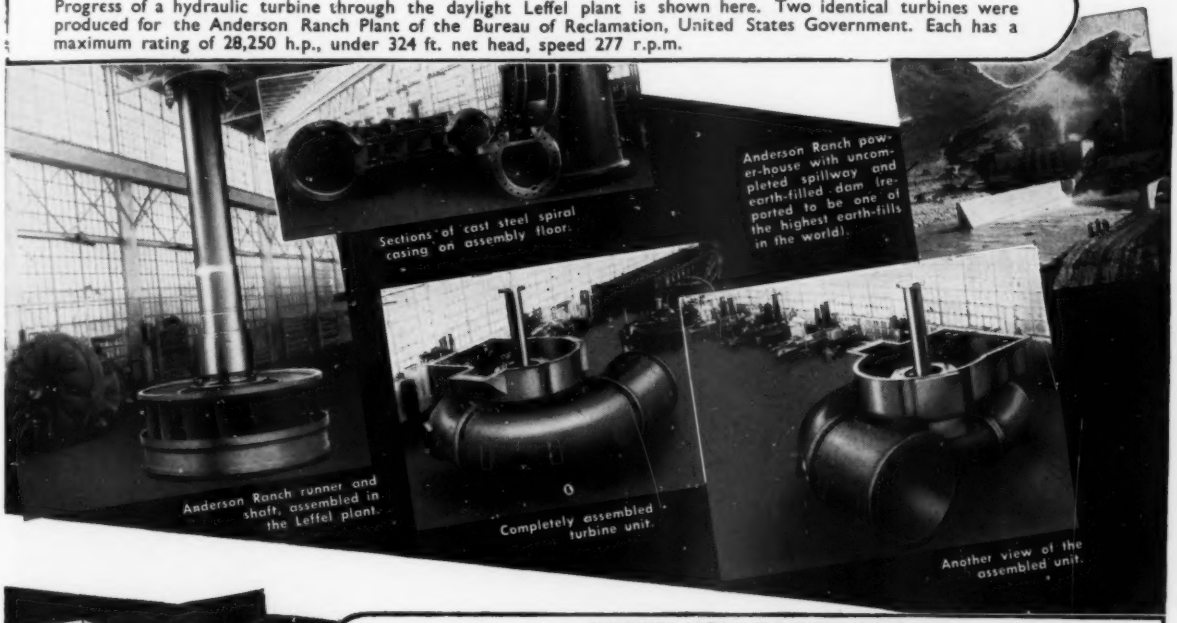
HYDRAULIC TURBINE

EFFICIENCY

Extreme care in every step of design and production within the modern Leffel plant insures maximum power and long-lived reliability in *every* Leffel hydraulic turbine. Leffel has a reputation for quality in design, materials and workmanship which frees your mind of worry from the minute you specify Leffel, for either a new installation or the rehabilitation of existing equipment. Call on us for advice and suggestions; you will find us courteous, helpful and thorough.

A TYPICAL EXAMPLE OF LEFFEL PRODUCTION

Progress of a hydraulic turbine through the daylight Leffel plant is shown here. Two identical turbines were produced for the Anderson Ranch Plant of the Bureau of Reclamation, United States Government. Each has a maximum rating of 28,250 h.p., under 324 ft. net head, speed 277 r.p.m.



Sections of cast steel spiral casing on assembly floor.

Anderson Ranch power-house with uncompleted spillway and earth-filled dam (reported to be one of the highest earth-fills in the world).

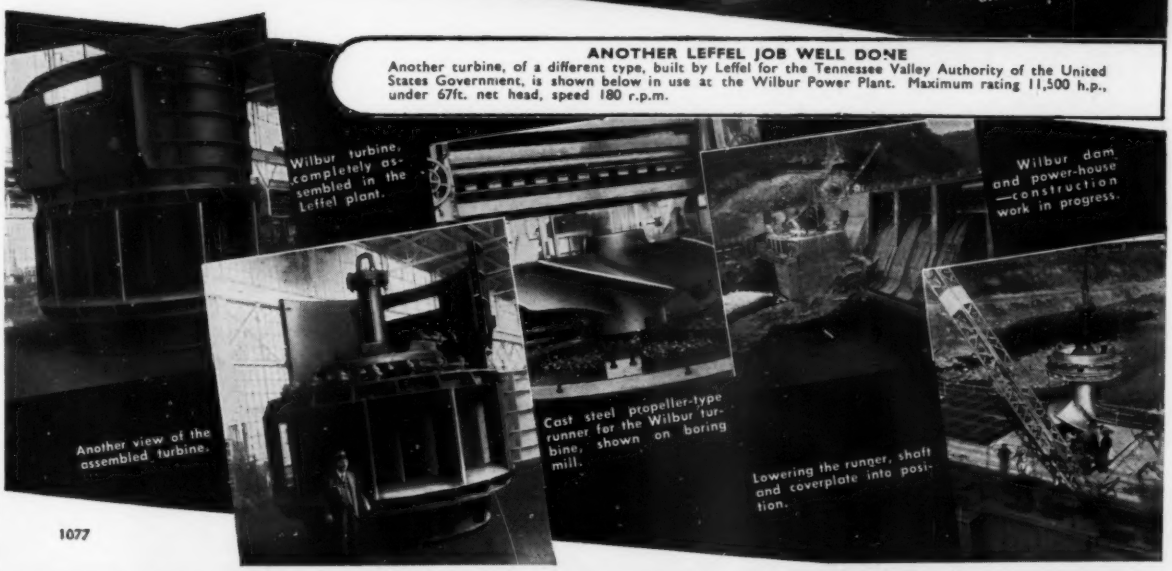
Anderson Ranch runner and shaft, assembled in the Leffel plant.

Completely assembled turbine unit.

Another view of the assembled unit.

ANOTHER LEFFEL JOB WELL DONE

Another turbine, of a different type, built by Leffel for the Tennessee Valley Authority of the United States Government, is shown below in use at the Wilbur Power Plant. Maximum rating 11,500 h.p., under 67ft. net head, speed 180 r.p.m.



Wilbur turbine, completely assembled in the Leffel plant.

Wilbur dam and power-house—construction work in progress.

Another view of the assembled turbine.

Cast steel propeller-type runner for the Wilbur turbine, shown on boring mill.

Lowering the runner, shaft and coverplate into position.

1077

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 89 YEARS

Keeping the Sea at Bay with MILLARS' WELLPOINTS

This amazing example of the efficiency of Millars' Wellpoint Dewatering System is actually in the sand on the seashore, within a few feet of the breakers. The excavation is 14 ft. deep below sea level and is entirely without supporting timber. The whole of this contract, which consisted of construction of a large outfall culvert in waterlogged sand, was carried out by the use of Millars' Wellpoints.

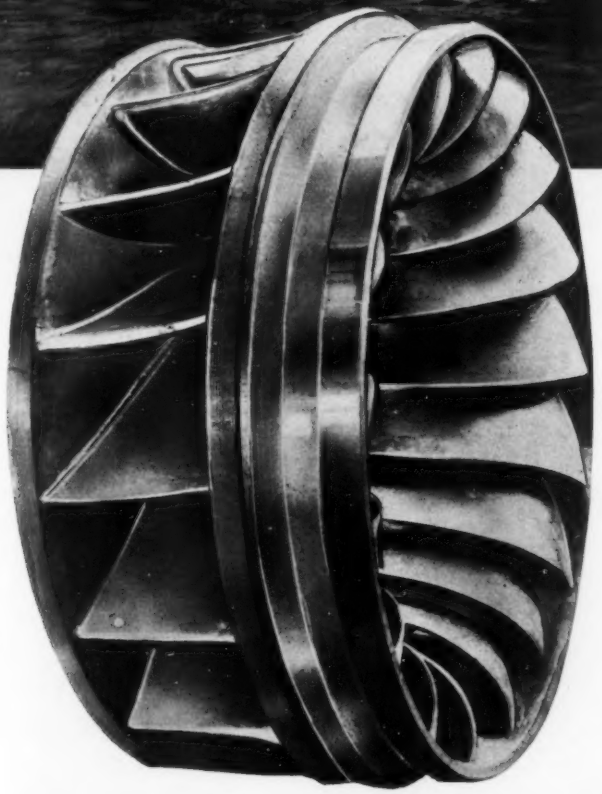
MILLARS' MACHINERY COMPANY LIMITED

Head Office : THORLEY WORKS · BISHOP'S STORTFORD · HERTS. Telephone : Bishop's Stortford 694

Wellpoint Dept. : CROMFORD HOUSE · CROMFORD COURT · MANCHESTER 4. Telephone : Blackfriars 8813

Harsprång

A view of the rapids after completion of the new dam.



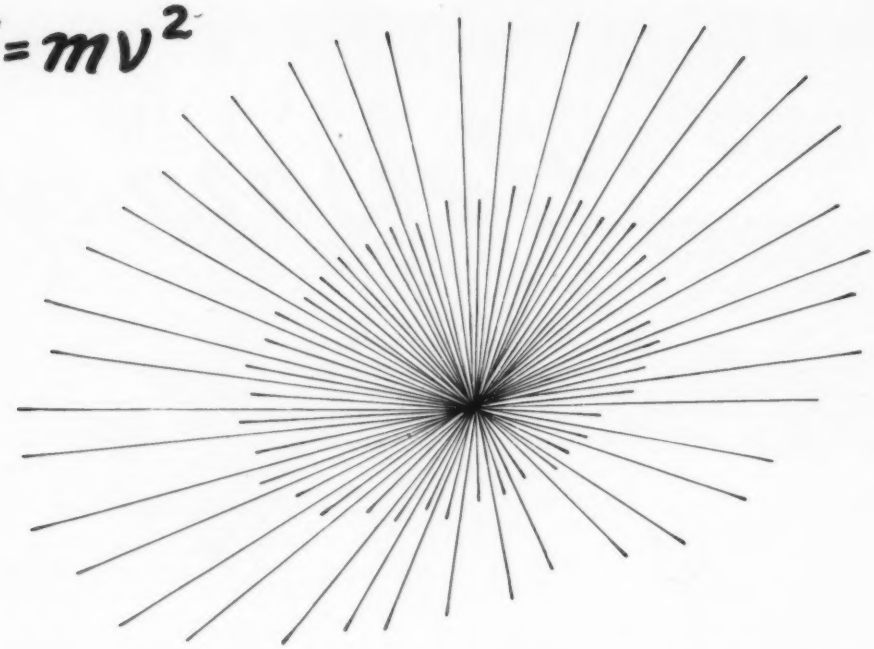
The Harsprang Power Station is situated north of the Arctic Circle and is owned by the Royal Swedish Board of Waterfalls.

Output 133,400 HP
Head 105 metres
Speed 167 r.p.m.
Water Quantity
107 cub.m/sec.

The runner for one of the Harsprang Francis turbines. Each runner is of stainless steel cast in one piece having a net weight of 35,000 Kilos.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD
KARLSTAD, SWEDEN

$E = mv^2$



...and the future

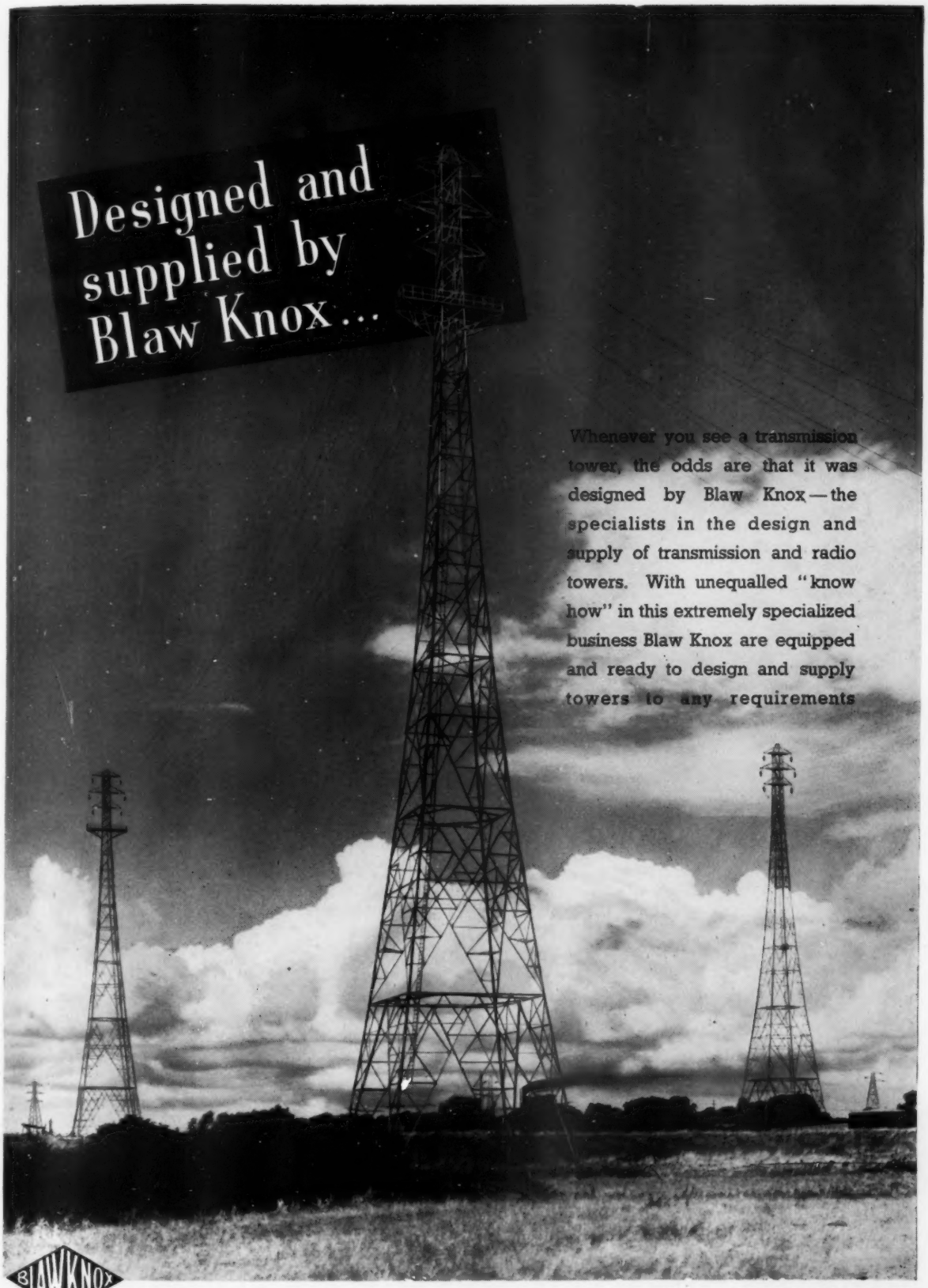
It is inevitable that nuclear energy will one day become a normal part of the routine of our lives, its use an every day occurrence, its control as consistently conformable to rule, and as much taken for granted, as electricity is today.

It is obvious that this control will require new forms of insulation, and undoubtedly somewhere in their construction porcelain will play a vital part . . . and it is equally obvious that only the finest porcelain will be good enough.

This being so it is certain that the stamp of Taylor Tunnicliff will be as much impressed on the future as it is upon the insulators of modern times.

TAYLOR, TUNNICLIFF PORCELAIN

TAYLOR, TUNNICLIFF & CO. LTD. *Head Office*: EASTWOOD · HANLEY · STAFFS · *Stoke-on-Trent 5272-4*
London: 125 HIGH HOLBORN, W.C.1. *Holborn 1951.* *Factories at: Hanley, Stone and Longton, Staffs.*


Designed and supplied by Blaw Knox...
Whenever you see a transmission tower, the odds are that it was designed by Blaw Knox—the specialists in the design and supply of transmission and radio towers. With unequalled "know how" in this extremely specialized business Blaw Knox are equipped and ready to design and supply towers to any requirements
BLAW KNOX

BLAW KNOX LIMITED · 55 CLIFTON HOUSE · EUSTON ROAD · LONDON · ENGLAND

BK53

All welded spherical pressure casing. Diameter 24 ft.

NOHAB

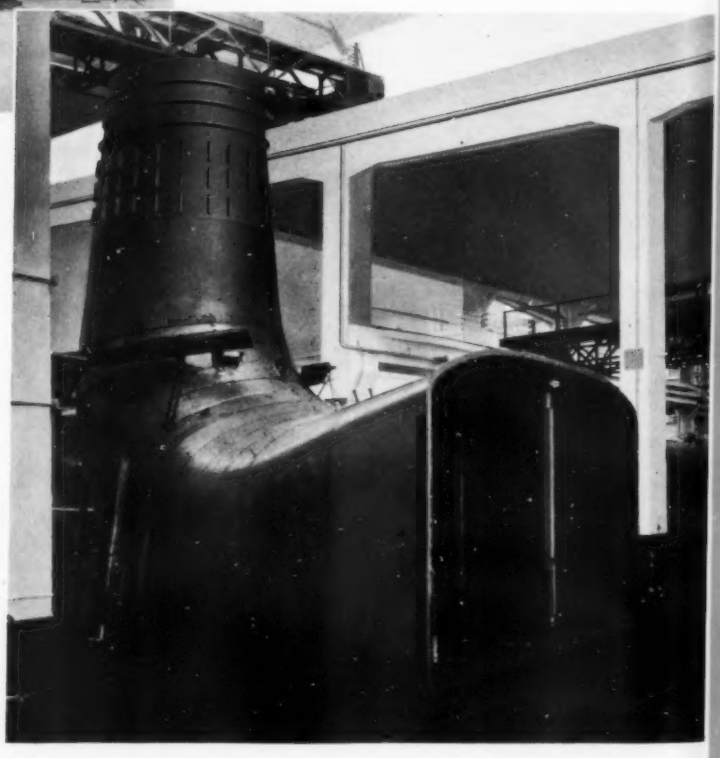
WATER TURBINES

GOVERNORS

CONTROL VALVES, GATES

AND OTHER EQUIPMENT FOR HYDRO-ELECTRIC POWER . . .

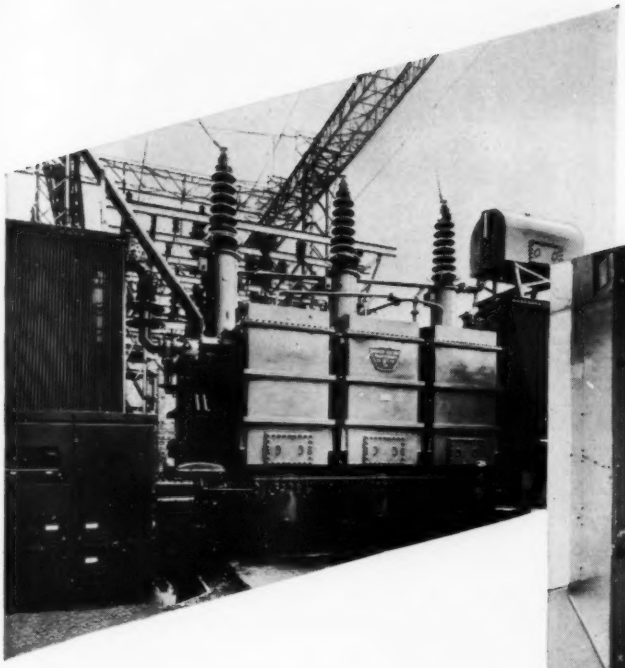
THE ILLUSTRATIONS show the pressure casing and the draft tube liner for a horizontal shaft twin Francis turbine with an output of 38,000 h.p. under a net head of 180 ft.

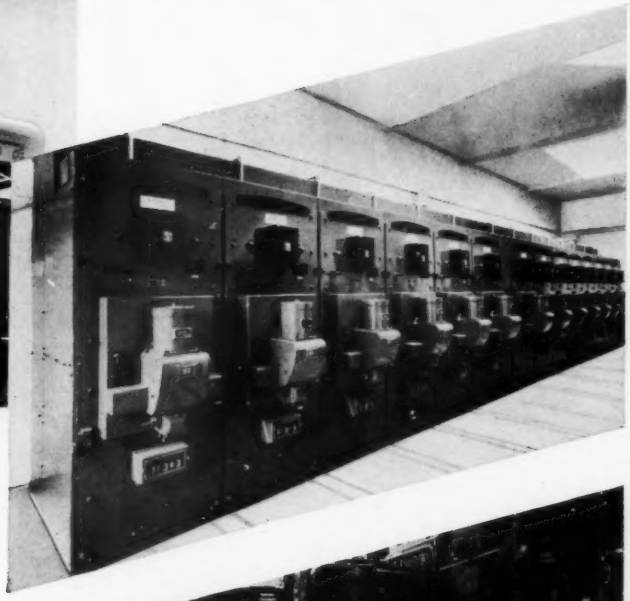


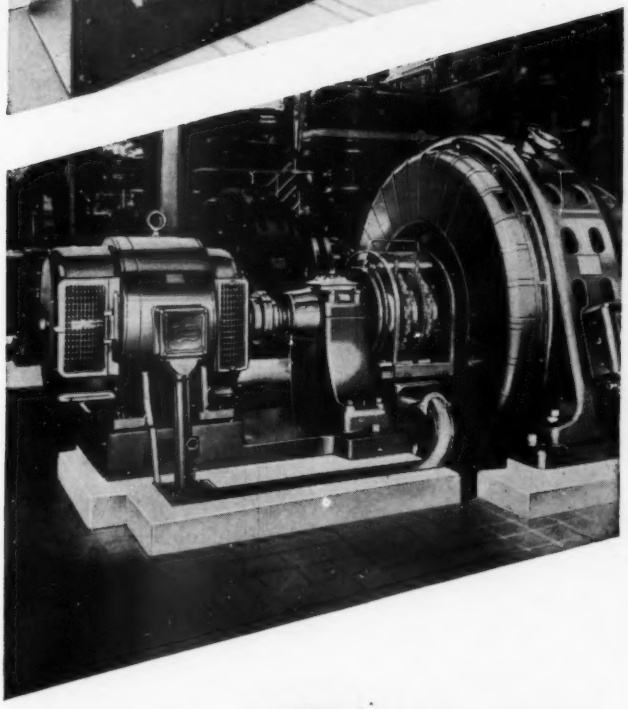
Draft tube liner

NYDQVIST & HOLM AKTIEBOLAG, Trollhättan, Sweden

Telegrams: Nohab, Trollhattan Codes: ABC 6th ed., Bentley's







Your new power project . . .

Be on the safe side right from the beginning. Specify transformers, switchgear, cables and rotating plant by Crompton Parkinson Ltd. Then you know beyond reasonable doubt that your major plant is right—as proved by hundreds of big installations all over the world. Crompton Parkinson Ltd. have been engineering electrical plant for over 70 years.

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METERS • CABLES • BATTERIES • HIGH EFFICIENCY CEILING FANS • ALTERNATORS
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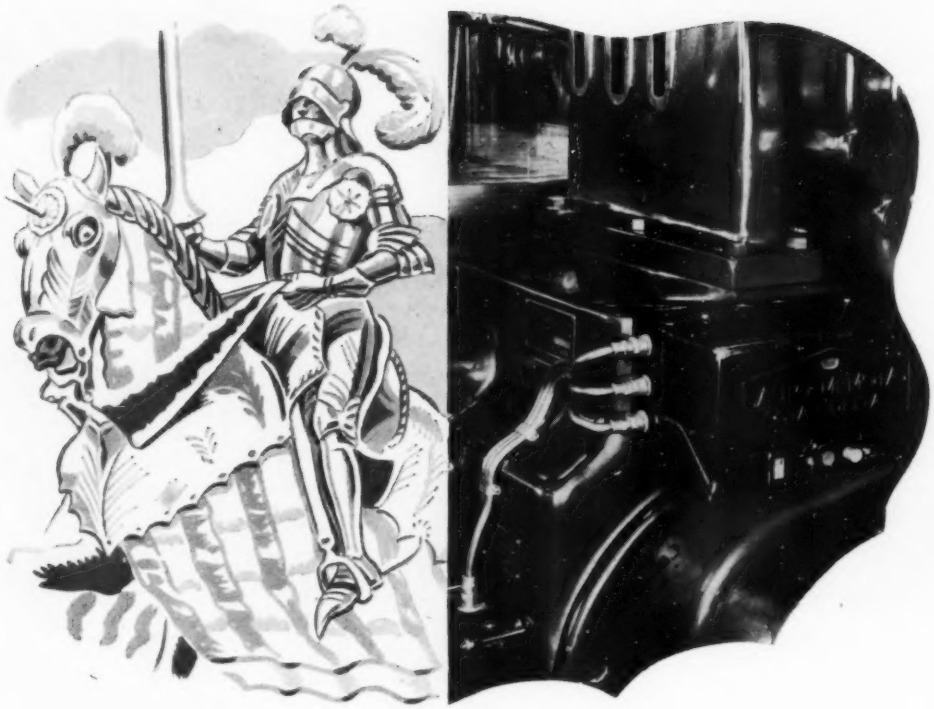

WHERE THERE'S RISK OF HARD KNOCKS

For real toughness and capacity to take punishment the knights of old were softies in comparison with "Pyrotenax" M.I. Cables. These copper clad cables will stand hammering, crushing, trampling on—can be exposed to oil, water, suds and condensation —in short, treated just like nothing on earth. Yet they will carry on year after year doing their job with dependable efficiency, requiring neither maintenance nor renewal. "Pyrotenax" M.I. Cables are also fire-resistant and unaffected by accidental overload. They can be bent to any shape and are easy to instal. They conform to all recognised requirements and are readily adaptable to all standard fittings.

Now giving satisfactory and permanent service in

ELECTRICAL GENERATING STATIONS, OIL PUMPING AND STORAGE INSTALLATIONS, FACTORIES AND WORKS, SHIPYARDS, DOCKYARDS, WARSHIPS, OIL TANKERS, PASSENGER AND CARGO SHIPS, RAILWAY WORKSHOPS, ROLLING MILLS, PAPER MILLS, TEXTILE MILLS, PRINTERIES, LAUNDRIES, BREWERIES, AERODROMES, FLATS, HOTELS, PICTURE GALLERIES, CATHEDRALS AND CHURCHES, THEATRES, SKATING RINKS, TURKISH BATHS, ETC.

PYROTENAX *Cables*
MINERAL INSULATED COPPER COVERED
For LOW TENSION LIGHTING, POWER & CONTROL WIRING

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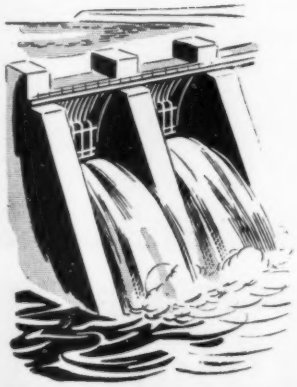
What's behind the nameplate?



TWENTY-FIVE years experience in design and manufacture and an output of **sixteen million kVA** of transformers, in all types and sizes, including some of the world's largest. Such figures are a true measure of excellence, for they could have been achieved only by the maintenance of the highest standard in design and construction and on a basis of long and reliable service.

HACKBRIDGE AND HEWITTIC ELECTRIC CO. LTD., WALTON-ON-THAMES, SURREY

Telephone: Walton-on-Thames 760 (8 lines) Telegrams: "Electric," Walton-on-Thames

THE two illustrations show views of a section of the Lochaber Power Scheme, which involved the construction of three large Dams, about twenty miles of concrete lined Tunnels, five Pipelines each 3,200 feet long, a Power House, Factory foundations, Tail Race and ancillary works.

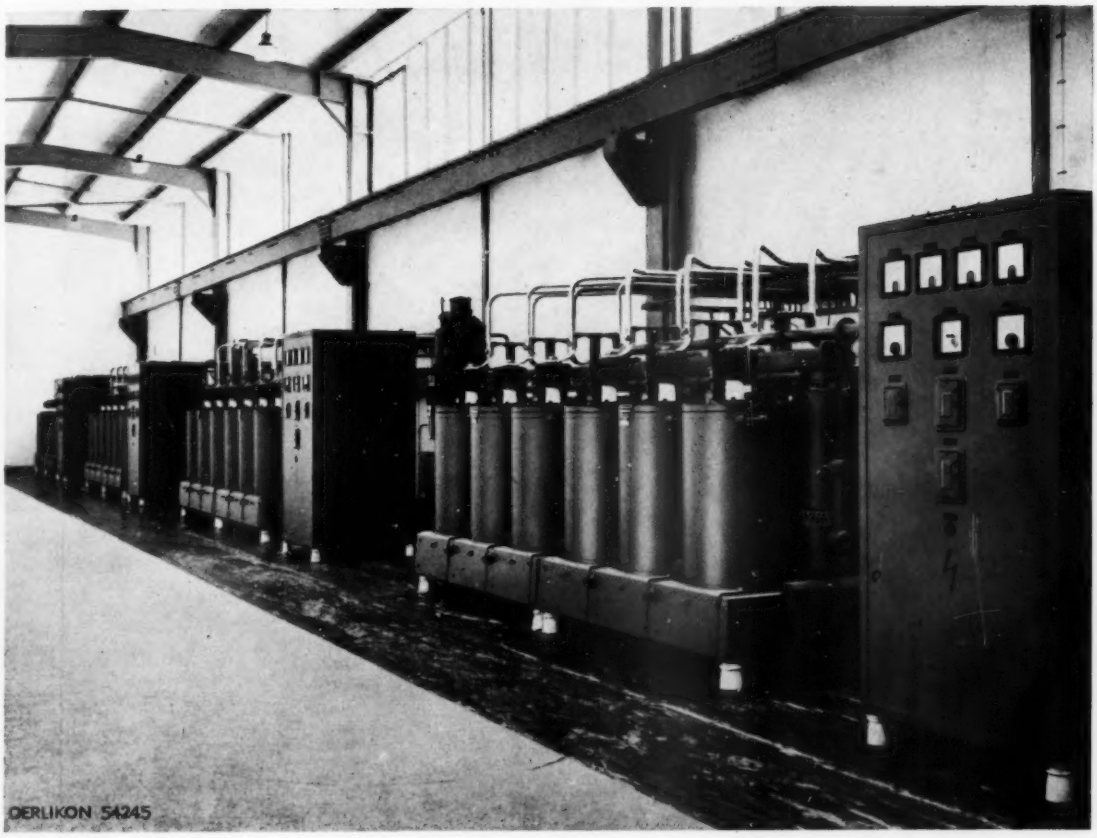
BALFOUR, BEATTY & Co. Limited

66 QUEEN STREET, LONDON, E.C.4. *Telephone CITY 2046 (15 lines) Telegrams: RUOFLAB, CANNON, LONDON*

AND AT EDINBURGH BAGHDAD NAIROBI BUENOS AYRES

OERLIKON

Electrical machinery and apparatus



Four Oerlikon single anode rectifier units each for 4500 kW, 6000 A, 750 V, in an electrochemical plant.

OERLIKON PRODUCTS:

Complete electrical equipments for hydro-electric and steam power stations, sub-stations and distribution installations.

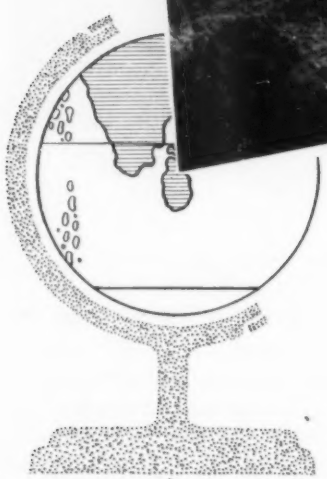
Generators, Motors, Transformers, Mercury Rectifiers, Induction Regulators ; Motor Generator Sets. **Electrical Apparatus** for High and Low Voltage (Oil Circuit-Breakers, Minimum Oil Circuit-Breakers, Air-Blast Circuit-Breakers, Isolating Switches, Step-Switches, Protective Switch-boxes, etc.) Voltage Regulators ; Relays, Lightning Arresters. Switch and Distribution Stations. Arc Welding Plants.—**Electrolysers** for the production of Hydrogen and Oxygen.

Steam and Gas Turbines. Turbo-Alternators.

Electrical Equipments for Locomotives, Motor Coaches, High-Speed Railcars, Diesel Electric Vehicles, etc. (for Standard and Narrow Gauge Railways, for Mountain and Rack Railways, etc.), Tramways, Trolleybuses, Ropeways, Cable Railways, Snow ploughs. —Compressors and Vacuum Pumps for Vehicles.—Rectifier Plants.

ATELIERS DE CONSTRUCTION OERLIKON, ZURICH 50 (SWITZERLAND)

CEYLON HYDRO-ELECTRIC SCHEME

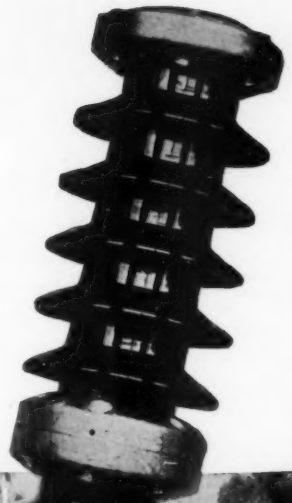


We have been privileged to co-operate in yet another important overseas hydro-electric contract—for the Norton Bridge Power Station at Hatton, Ceylon.

For this contract 2,000 tons of South Durham Steel Pipelines were manufactured, erected, and welded and tested in situ by South Durham engineers and skilled workmen. Our experience in this field and the assistance of our advisory staff are always at your service.

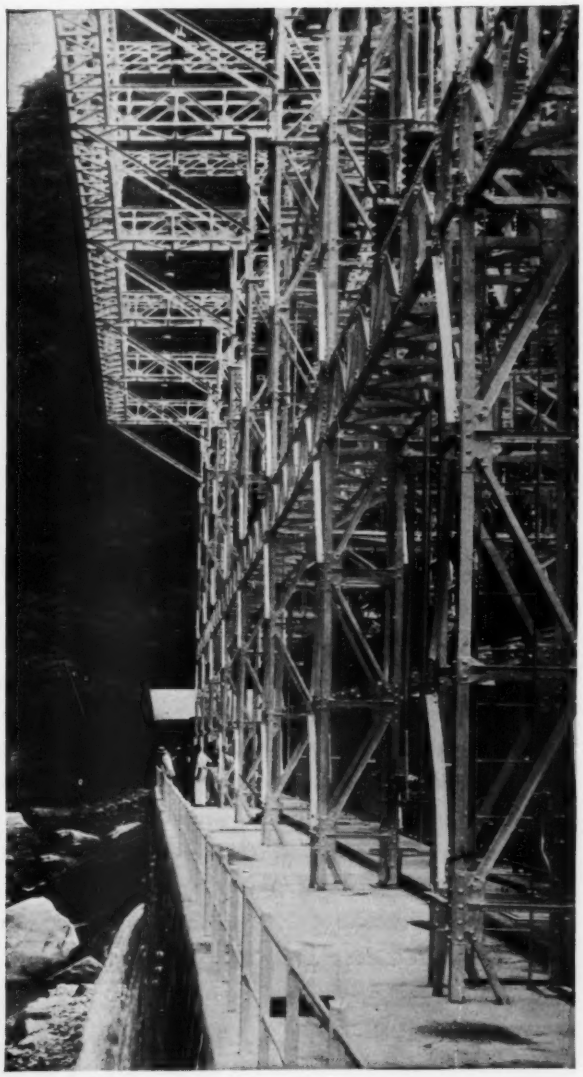
SOUTH DURHAM STEEL PIPES

South Durham Steel & Iron Co. Ltd., Pipe Dept: Stockton-on-Tees. Phone: Stockton-on-Tees 66117.



S.P.P. Post Insulators were specified for the 110kv outdoor switchgear on the Jog Falls Hydro-electric Scheme

The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.



STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire Telephone: Stourport 111 Telegrams: Steatain, Stourport

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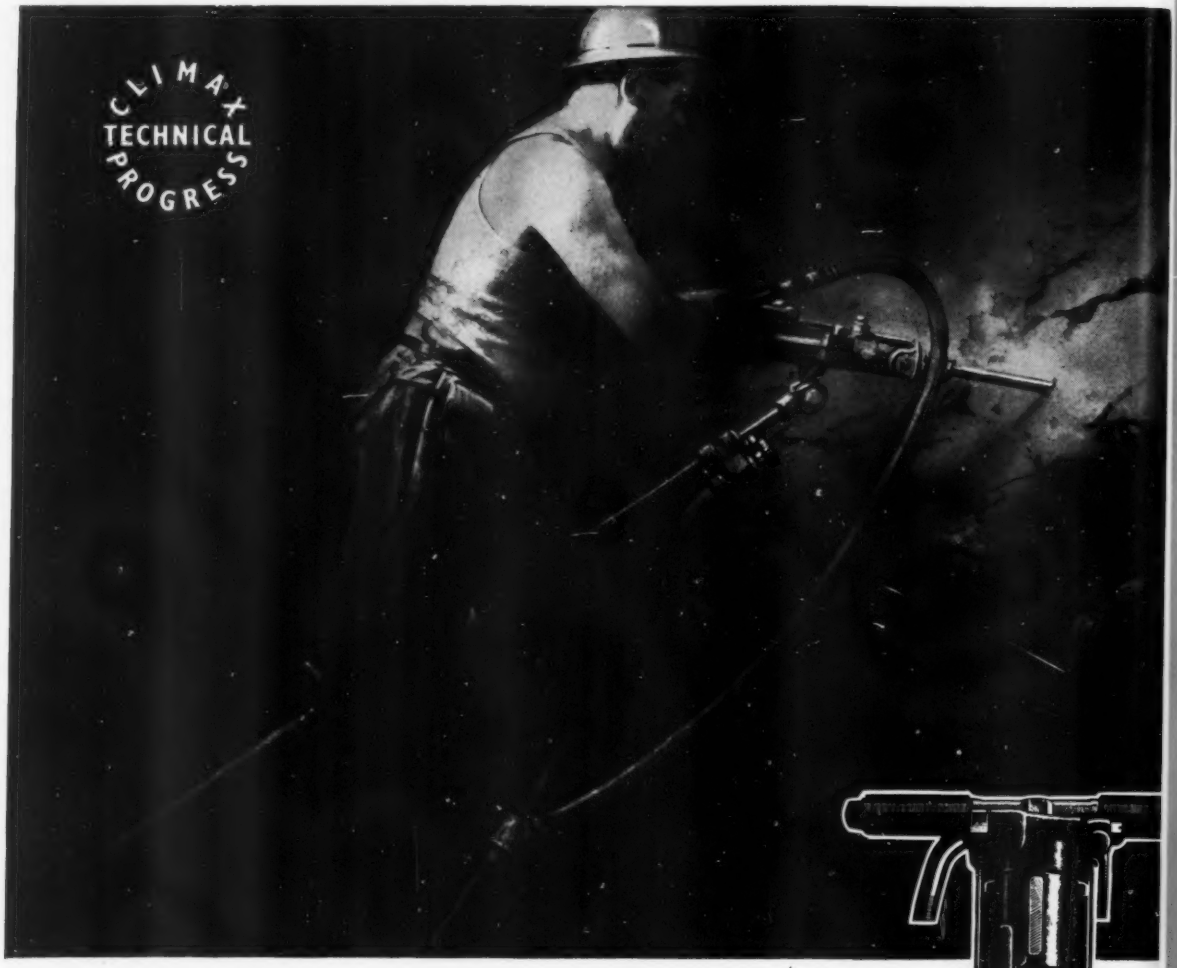

GREATEST FOOTAGE—LEAST FATIGUE

The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

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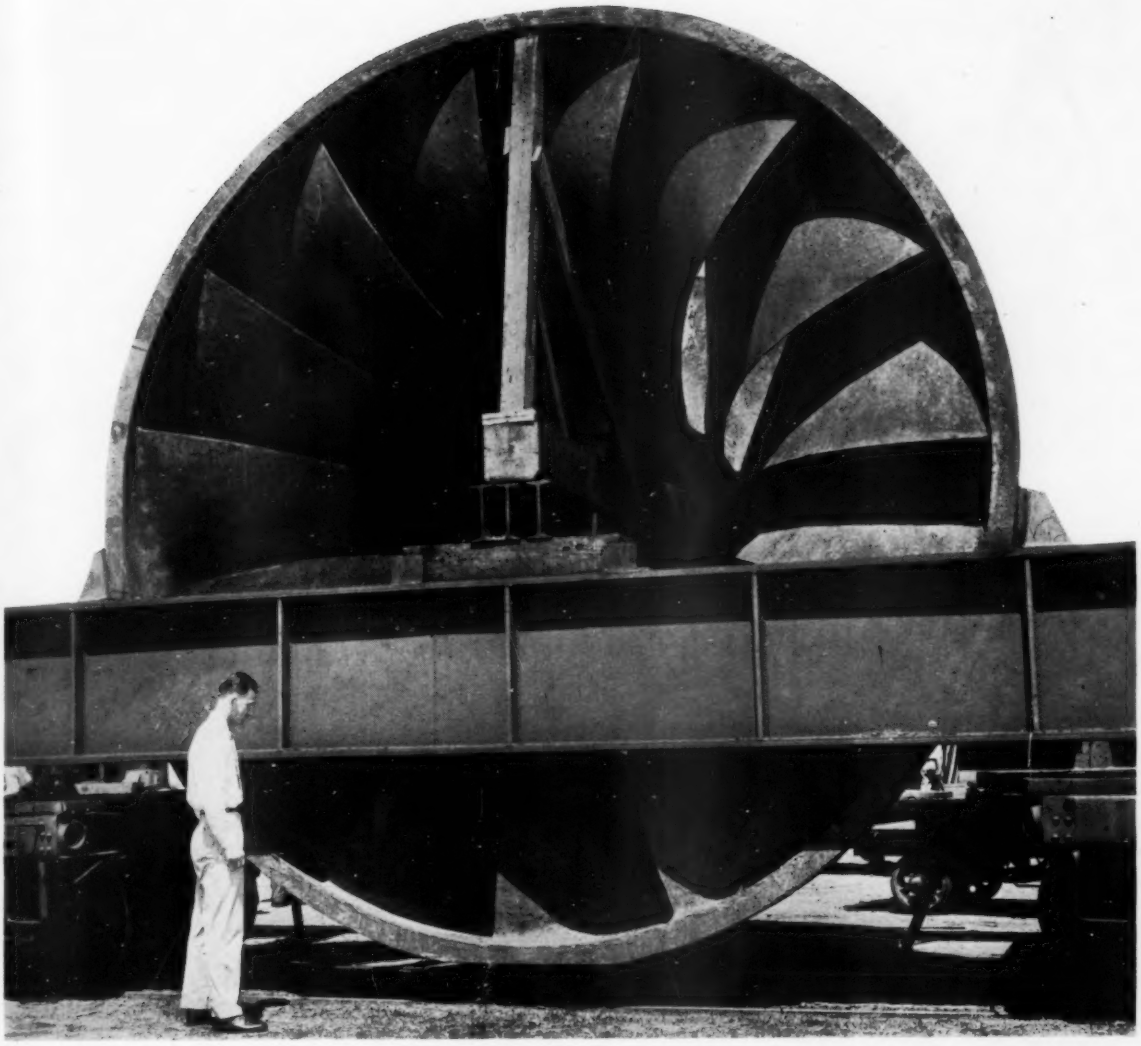
CLIMAX ROCK DRILL & ENGINEERING WORKS LTD.

4, Broad Street Place, London, E.C.2. Works: Carn Brea, Cornwall.

TAS/CX 480



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The 225-acre Newport News plant includes plate steel and machine shops equipped with a complete variety of tools to fabricate items of water power equipment of any size. Contracts received by Newport News for hydraulic turbines with an aggregate rated output in excess of 7,000,000 horsepower have included units as high as 165,000 horsepower and as low as 500 horsepower.

Supplementing the extensive facilities are the equally important experienced and skilled personnel at Newport News to design and build such equipment.

Your inquiries for hydraulic turbines of any size will receive prompt attention.

Write for illustrated booklet on water power equipment.

NEWPORT NEWS

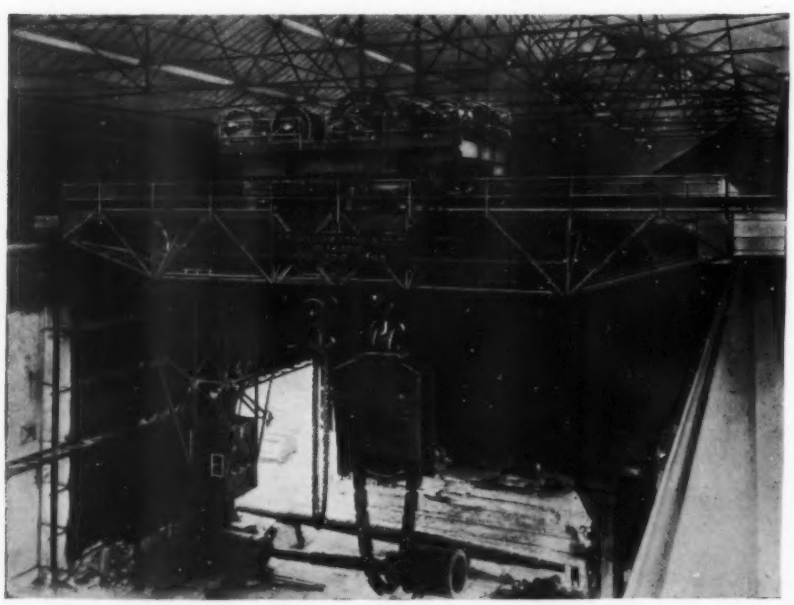
SHIPBUILDING AND DRY DOCK CO.

NEWPORT NEWS, VIRGINIA, U.S.A.

Arrol: Cranes

of course and a hundred and one other structures . . .

FULL SWING AT ARROL'S has immense reach. It covers responsibility for the design and manufacture of the largest projects engaging mechanical, hydraulic and power engineering, heavy steel construction and the development of new tools and equipment. From the listing of products it will be seen that Arrol's fame as Bridge Builders is only one chapter in a volume of world activity, the whole of which is very impressively greater than its most distinguished part.



All types of Steel Framed Buildings, Fixed and Opening Bridges, Cranes and Mechanical Engineering Work, Dock Gates, Sliding and Floating Caissons, Compressed Air Locks, Hydraulic Machinery, Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Stations.

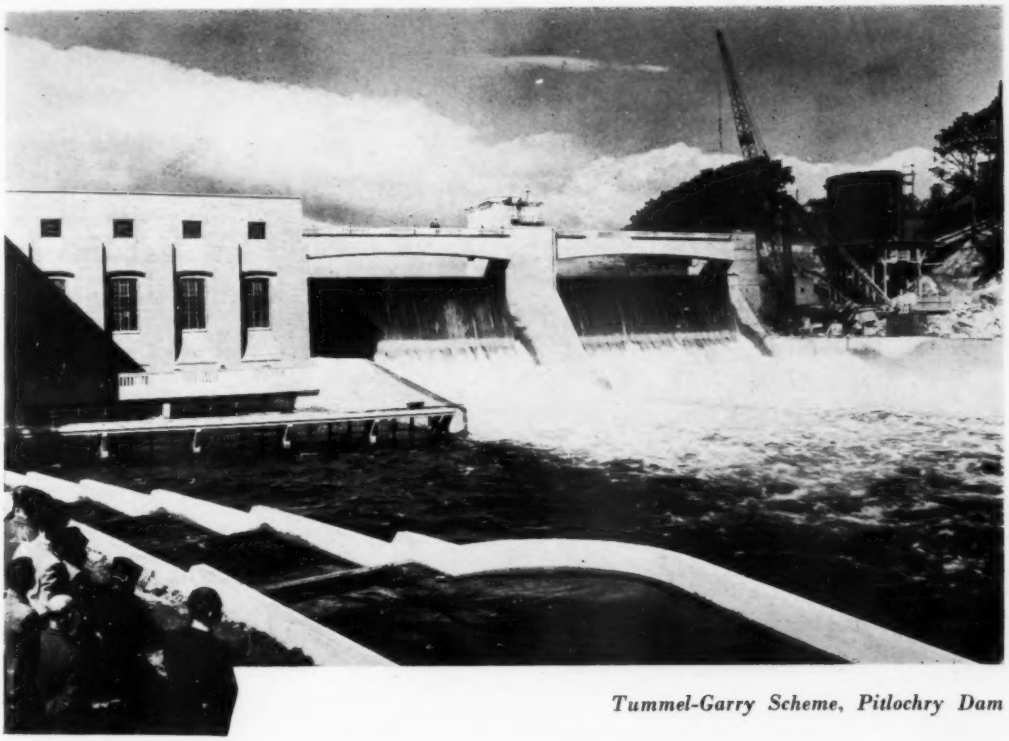
The illustration shows a 300-ton forge crane with electric turning gear.

ARROL

SIR WILLIAM ARROL & CO. LIMITED, GLASGOW

Hopwood

SHOP WINDOW FOR BRITISH ENGINEERING



Tummel-Garry Scheme, Pitlochry Dam

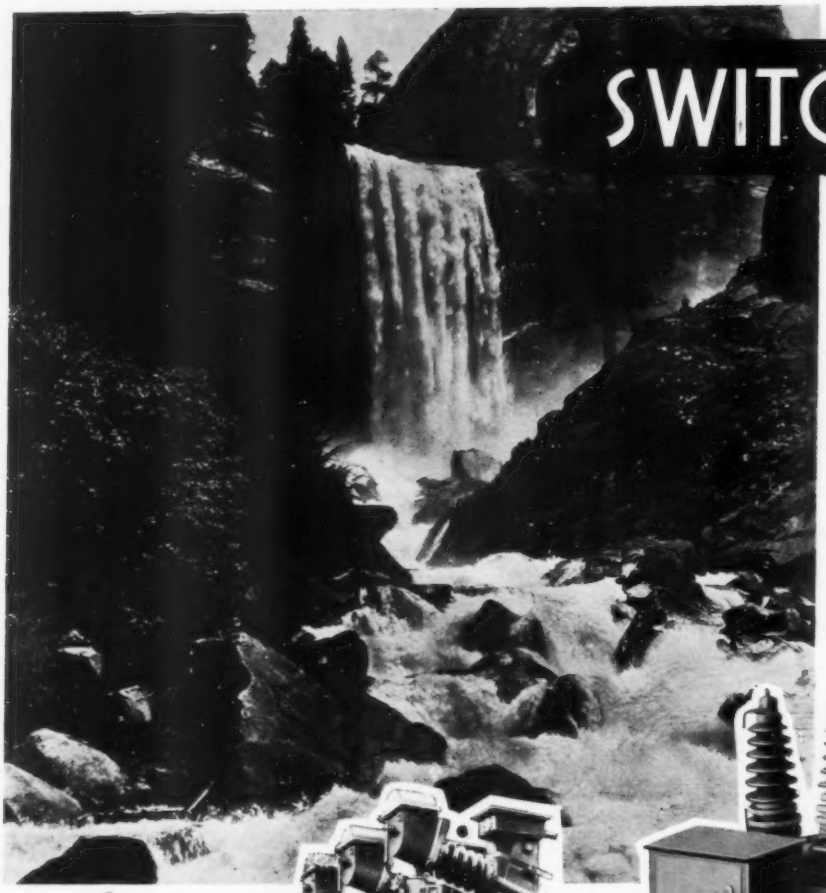
The North of Scotland Hydro-Electric Board are harnessing the water power resources of the Highlands of Scotland, which are estimated to have a potential annual output of 10,000,000,000 kilowatt hours, distributing electricity in an area of 21,750 square miles and also supplying power to Britain's National Grid.

More than one hundred hydro-electric schemes are visualised in this development.

Schemes with an estimated annual output of 3,300,000,000 kilowatt hours and a kilowatt capacity of 1,126,000 are in operation, under construction or in preparation.

On the doorstep of world-famous engineering firms the visitor will see a wide range of generating machinery and equipment operating under diverse conditions.

NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD



SWITCHGEAR

for

HYDRO ELECTRIC SCHEMES

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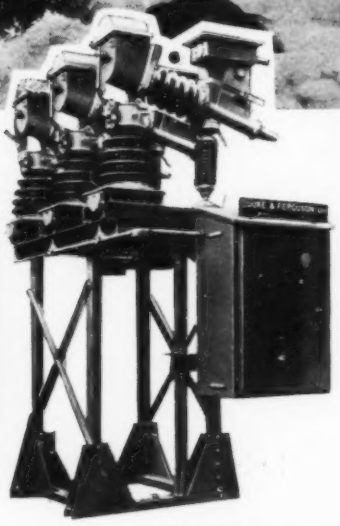

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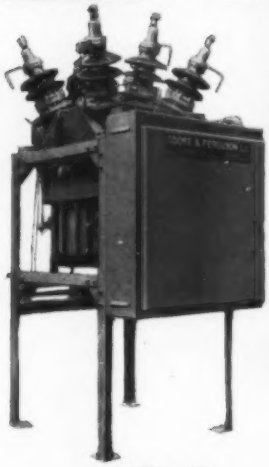

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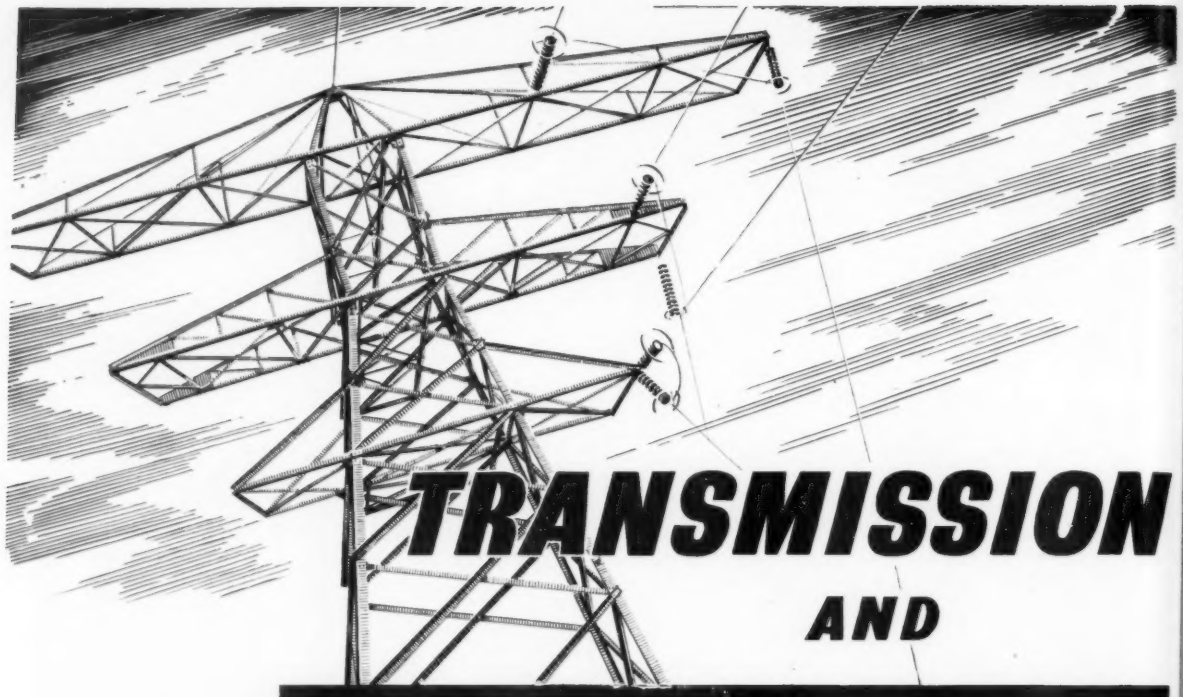

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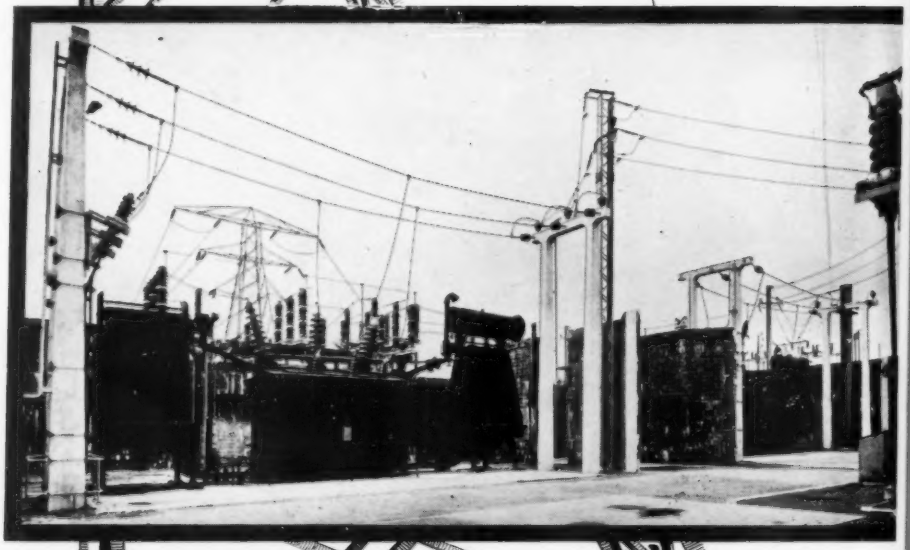

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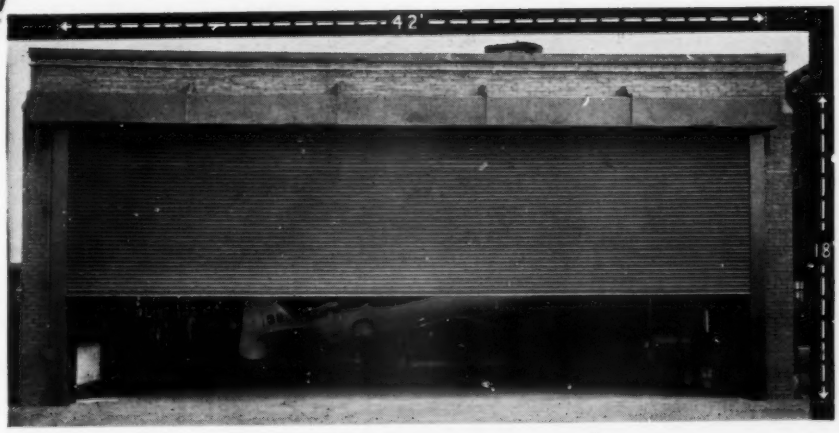

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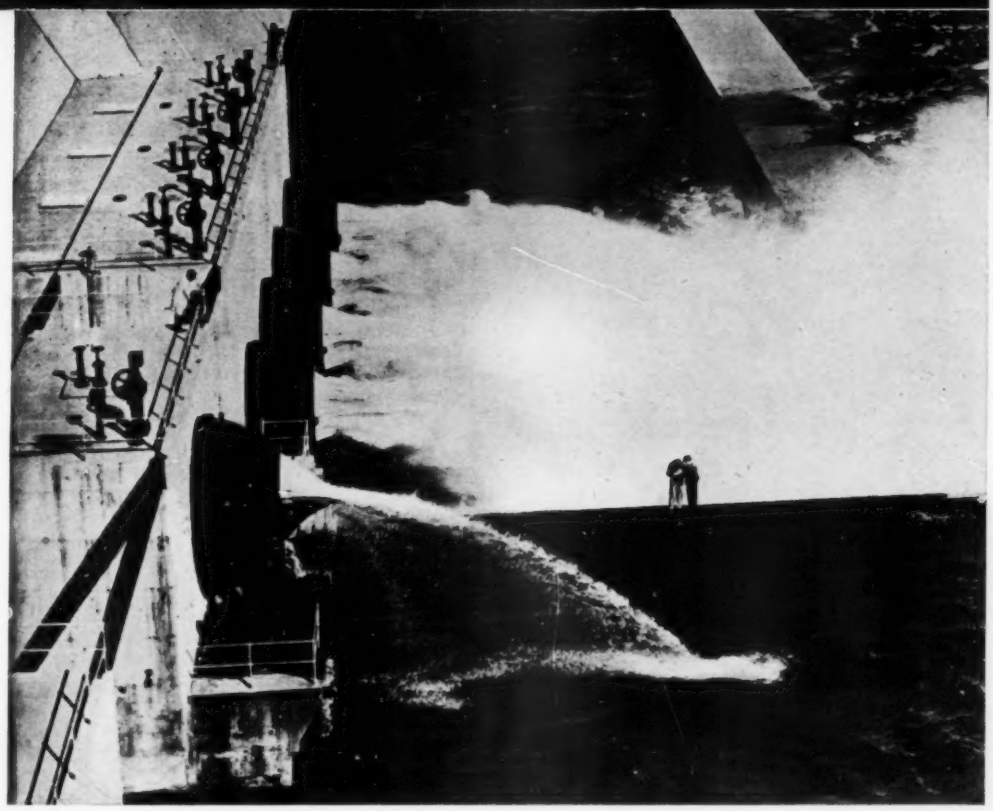

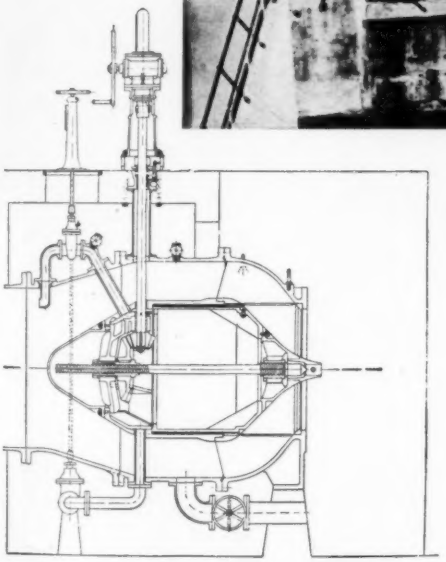

The Larner-Johnson valve possesses exceptional qualities for free discharge control. No other valve provides so complete an answer to the dual problems of high velocity flow and hydraulic unbalance associated with this duty. Being of true streamline form, it passes a smooth jet at all openings, giving freedom from vibration and erosion under the highest heads. Operation is by means of the pipe line pressure acting on the plunger, governed by an internal pilot valve control which holds the plunger in balance at all open positions (when stationary) and creates the appropriate unbalance for opening or closing. Ease of operation is thus ensured, irrespective of size or pressure. Simplicity of design, freedom from distortion troubles, absence of sliding surfaces under pressure, all contribute to the success of the valve over the full range of conditions. Some of the largest valves of their class are of Larner - Johnson type, amongst them the three 13 ft. by 7 ft. 6 in. and four 9 ft. by 7 ft. 6 in. regulators at Hume Dam, on the Murray River, Australia, certain of which appear in the adjoining photographic view.

Full particulars from : **J. Blakeborough & Sons Ltd.**, Brighouse, England.

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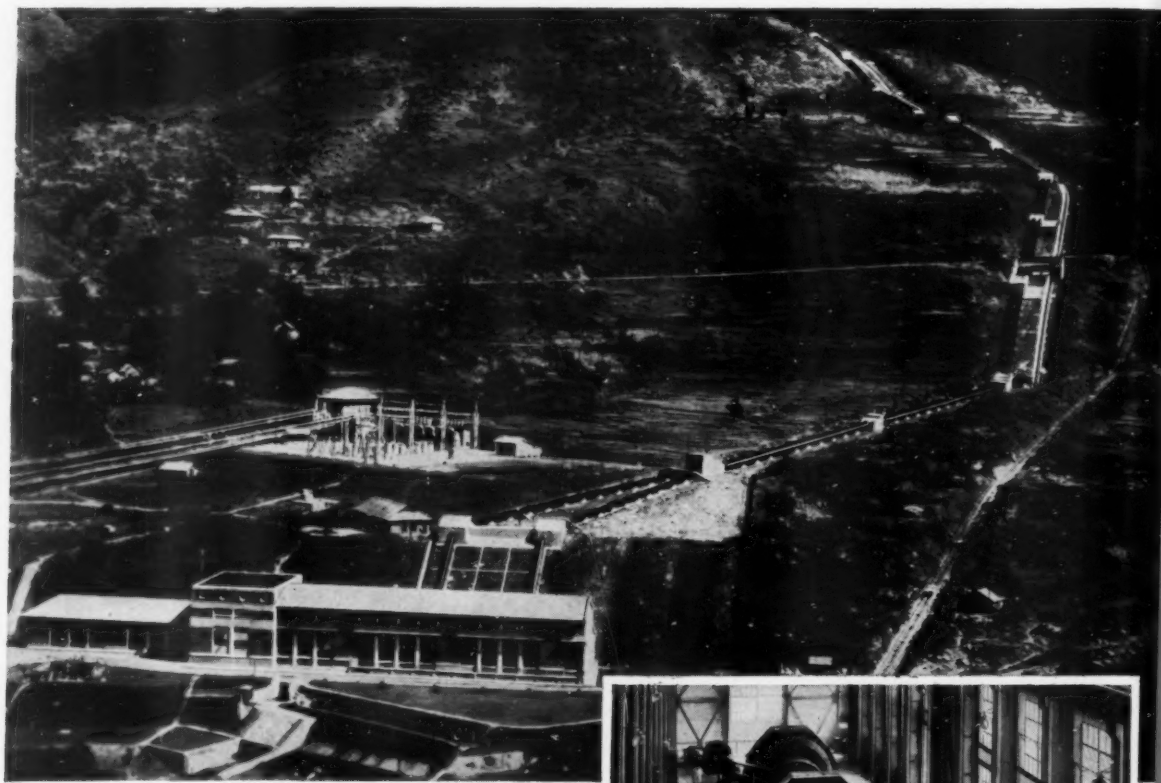
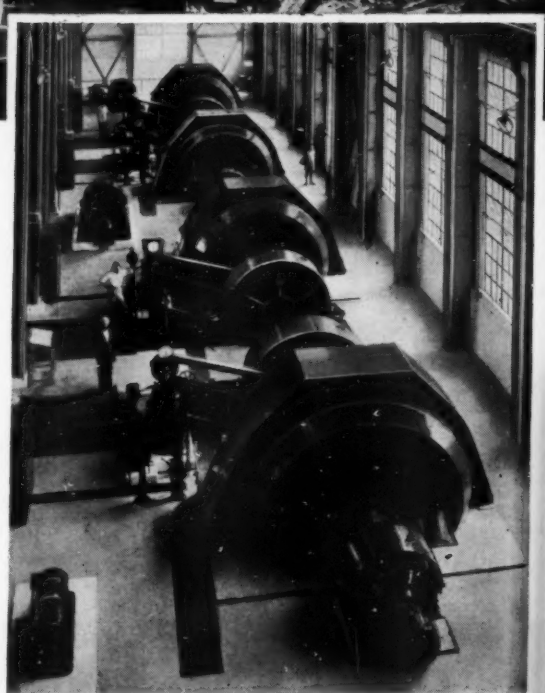
Hydro-electric Equipment





General view of Shanan Power Station

Four three-phase, waterwheel-driven alternators, (horizontal type, 13,333 kVA., 428 r.p.m., 11,000 volt, 50 cycle) installed in Shanan Power Station for the Punjab Government's Uhl River Hydro-electric Scheme.

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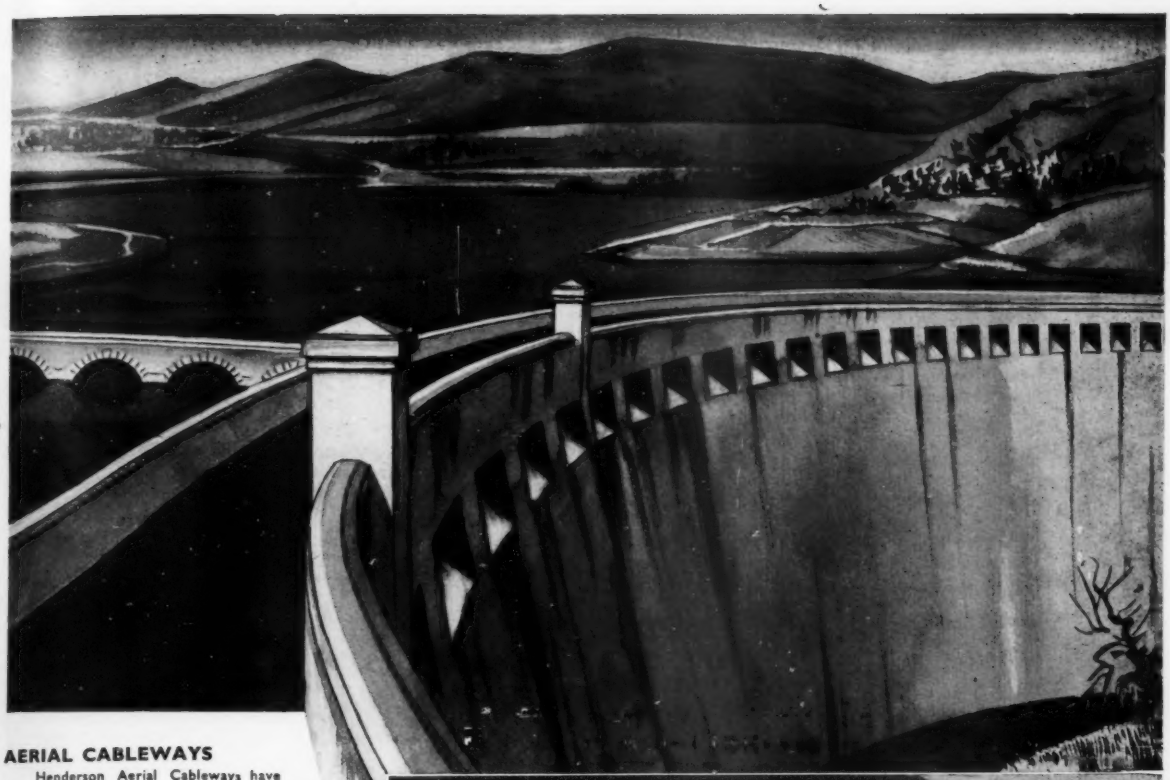

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View of Henderson Cableways during the construction of the Claerwen Dam, courtesy of the Birmingham Corporation Water Works. Contractors Messrs. Edmund uttall Sons & Co., Ltd.

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Aerial Cableways

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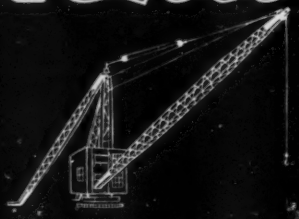
FOR HYDRO ELECTRIC SCHEMES



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Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
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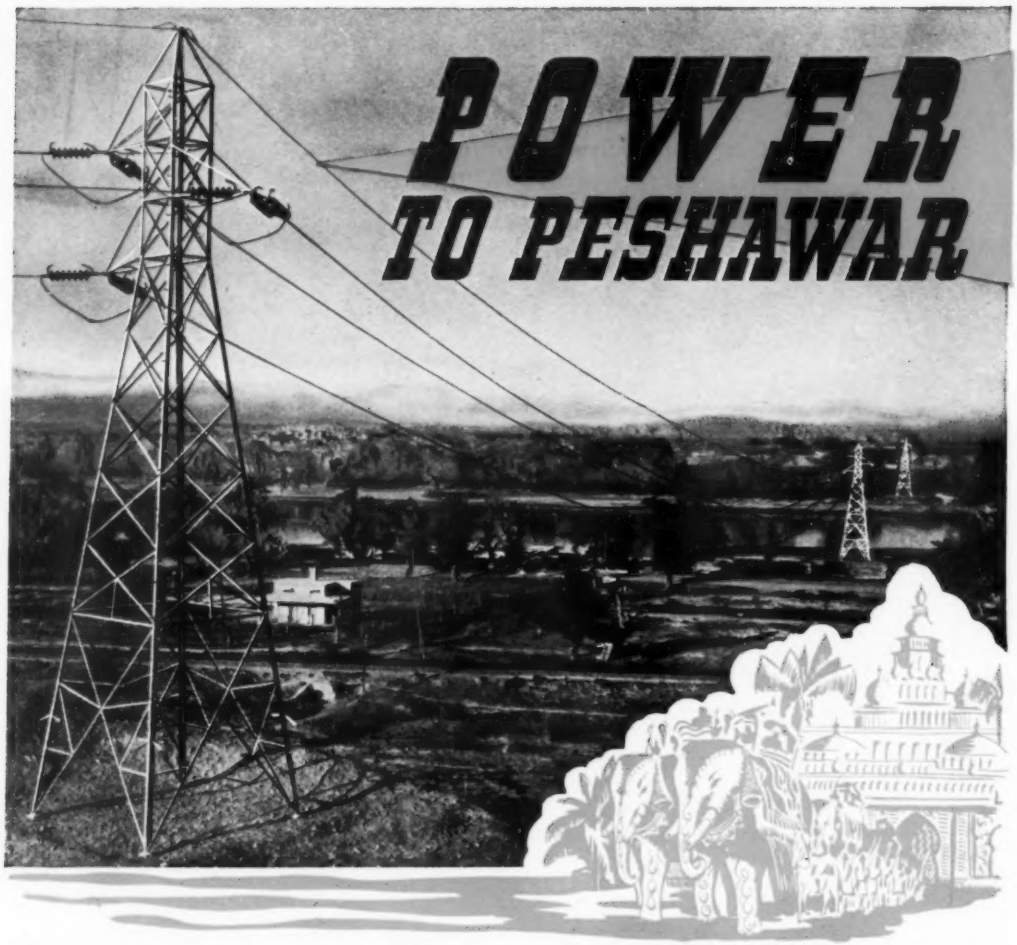

Water from a tributary of the River Indus provides power for the Malakand hydro - electric station, high in Pakistan's North West Frontier Province.

To bring current down to Peshawar and its neighbouring districts, BICC erected over a hundred miles of 66 kV single and double circuit overhead power transmission lines for the Public Works Department.

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The Training of Hydro-Electric Engineers

IN this age of severe specialisation it is a matter of some moment as to how a hydro-electric engineer should be trained. Probably in no other branch of the profession is a greater diversity of knowledge required — civil, mechanical and electrical — and it must be conceded that no one man can have the attributes of a good civil engineer, turbine builder and generator designer. That would be asking for the impossible; on the other hand, it is very desirable that each man should have an appreciation of the problems facing the others, and most particularly is this true of those responsible for the two sections of the generating machinery—the turbine and the alternator.

How then can a man be suitably trained to investigate properly the merits of a hydro-electric project? It is true that a team of experts can be called upon, each member confining himself to his own particular sphere, but such an approach is uneconomical and still demands the services of an arbitrator to smooth out the possibly conflicting desires of the specialists; and such an arbitrator must be reasonably well versed in all branches.

We may first consider who in the build-up of a complete scheme has to undertake the widest responsibility. If a scheme is to be judged on the basis of the money to be expended, then undoubtedly the basic knowledge should be civil engineering, but the pure civil engineer can successfully apply his knowledge with little or no appreciation of the characteristics of either the prime mover or the generator. Likewise an electrical engineer can play his part in the design of the generator, transformers, switchgear or transmission lines without any knowledge of how the water is derived or how it is utilised by the turbine. The prime-mover expert on the other hand must have at least an appreciation of generator design to assist him to choose a suitable type of turbine; he must furthermore have at least an elementary knowledge of transformers, switchgear and transmission lines in order to advise on station capacity and sizes of units, while on the civil engineering side his knowledge must be more than elementary since it is he who often determines the sizes of the conduits, the location of the power house foundations and even, in some circumstances, the most suitable intake water level (and thus height of dam) to give the most economic solution in a particular case.

In countries where water power engineering is given much attention the predominating part played by the mechanical engineer seems to a great extent to be recognised; this is the case, for example, at the Massachusetts Institute of Technology and Passadena University in the U.S.A.; Zurich Polytechnic in Switzerland; Toronto University in Canada; and Munich University in Germany. Where, however, these seats of learning appear to differ from British views is in the comparative rareness with which modern trends in electrical design are also taught. Probably, therefore, any man aspiring to become a true hydro-electric engineer would find that his best course would be to take a mechanical-hydraulic course at a University, follow this with an apprenticeship in both an electrical and a hydro-electric turbine works, and finally obtain further knowledge of his profession by assisting in the erection of plant on site.

Such an extended course of study may sound somewhat idealistic but it is already recognised that to produce a good hydro-electric engineer entails long and careful training, and one of the Colleges of London University has already, with the co-operation of a well-known firm of hydro-electric engineers, instituted a twelve months' post-graduate course in hydro-electric engineering in which the civil engineering aspects are fully considered together with

advanced hydraulics and turbine and generator design.

That the time required is long must certainly be admitted but it is no longer than the period for a man to become a competent doctor and few are deterred from entering that profession only on the score of the time needed to qualify.

Loan to Thailand

OF the three loans totalling together nearly 25½ million dollars, granted to the kingdom of Thailand by the International Bank for Reconstruction and Development, one, amounting to 18 million dollars, is connected with the construction of a barrage across the Chao Phya river, near Chainat, about 100 miles above Bangkok. This project, like many others of its kind in other countries, is intended to be of a dual character. While primarily designed for the irrigation of the rice lands in the central plain the barrage will be so constructed as to allow for the later installation of hydro-electric power plant to supplement the present thermal capacity in the capital. The loan is for a term of 20 years, and carries an interest rate of 3 per cent. per annum. Amortisation payments will begin in April, 1956.

River Diverted Underground

IT is hoped during the next year or so to complete the third unit of Sweden's Hjalta power plant near Langsele, Lapland, which was opened by the King of Sweden towards the close of last year. When this addition is complete the total annual capacity of the plant will be 1,000 million kWh. Remarkable features of this installation—incidentally part of an immense project which has been under consideration since the beginning of the century—are the construction of a tail-race tunnel four miles in length blasted through rock, and a diversion of the Fax River, a tributary of the Angerman River, to an underground course with an 80 metre head. The two turbo-generators now operating in this subterranean plant are the most powerful in the country. From three large intakes at Hjalta the Fax waters enter penstock shafts to the turbines 80 metres below, thence continuing at an easy grade through the tail-race tunnel which empties into the Angerman some four miles away. The new plant took six years to build and cost Kr. 100 million (approximately £6,900,000). Eighty-five per cent. of the share capital is held by Sydkraft A.B., leading light and power suppliers, and the remainder by Kramfors A.B., producers of forestry materials.

India's Wasted Water

LESS than two per cent. of the hydro-electric potential of India has thus far been developed, and less than six per cent. of the water flowing yearly through her rivers is being utilised for irrigation. Yet, as pointed out in "India Record" (the news digest issued by the High Commissioner for India through his Public Relations Department), there is no field in which the significance of long-term planning is greater than in the utilisation of irrigation and power resources of the country. New irrigation works have now to be based on storage rather than diversion, which was the method under earlier schemes. Consequently they are more costly, but the Rs. 590 crores for 113 projects now in hand are expected to provide 2 million kW of power and bring 13 million acres under irrigation. Fifteen years is the extent of the period over which the Planning Commission suggests present proposals should range.

8m. Dollar Contract

THE Newcastle-on-Tyne (England) engineers, C. A. Parsons and Co. Ltd., received towards the end of the old year a further order for two turbo-alternators from the Hydro-Electric Commission of Ontario. This brings the total order to four, at a cost of 8 m. dollars. It is understood the alternators will be delivered in Canada during 1952.

World Bank and Pakistan

HYDRO-ELECTRIC schemes doubtless ranked high in the subjects discussed by the World Bank Mission which visited Pakistan towards the close of 1950. Some of these schemes, and their part in the development of the new state, are examined in an article by our special correspondent elsewhere in this issue. The Pakistan Government has applied to the bank for loans aggregating £80 million (Rs. 750 million) to be devoted largely to these schemes and to others affecting land and industry generally. To a great extent the question of a loan has been bound up with the controversial issue of the exchange rate of the Pakistan rupee, a subject of protracted discussion between the government and the International Monetary Fund. The outcome of these discussions is important because it involves the future of Pakistan's trade with India. The Government of India, through its Finance Minister, Sir Chintaman Deshmukh, had intimated that his government was not prepared to resume trade exchanges with the Pakistan rupee at an exchange rate of approximately 2s. 2d.

A New President

MR. JAMES WILSON has resigned the presidency of the Shawinigan Water and Power Company on account of ill-health. As the company's sixth president, he directed its affairs for 11 years, during which time it and all the associated companies have greatly strengthened their position as important parts of the Canadian business company. Three associates of Mr. Wilson have been promoted: J. A. Fuller, as president; R. J. Beaumont, as chairman of the board; and J. B. Challies, as senior vice-president.

Electric-Power Distribution System

WHEN planning a distribution system for any plant the following basic conditions must be considered, according to a study by L. Chapin, Sargeant and Lundy: (1) type of industry, (2) amount of load to be handled, (3) importance of uninterrupted service and (4) plant area. With this information, the authors point out, a study can be made to decide the following

problems: scheme of distribution; location of distribution centres; best voltage to use.

The authors have followed this outline in tackling several types of installations. Covered are the problems that cropped up in development of the systems and the way they were handled. In these studies a paper-board mill, a large educational institution and a steel mill were taken as fitting subjects.

Conclusion of the studies is that each installation is an individual problem that defies any standard formulation. Hence the need for the basic approach outlined above.

The Trenche Development

QUEBEC'S newest great hydro-electric development—the Trenche generating station—which was opened in December, produces 325,000 horsepower. This is the sixth big station of the Shawinigan Water and Power Company on the St. Maurice River alone, and the 15th in the company's complete system.

The Trenche development, located 130 miles up the St. Maurice from Trois Rivieres and just below the mouth of the Trenche river, is six miles below the Rapide Blanc development. It was designed and built by the Shawinigan Engineering Company Ltd., subsidiary of the parent company. Work was begun two years ago, and all five generators will be in operation by early summer.

Ontario Seeks British Workers

THE Hydro-Electric Power Commission of Ontario has embarked upon an expansion programme and has several large construction projects in hand. The largest of these current projects has just commenced in Niagara Falls, Ontario, where 157 million dollars will be expended in electrical construction during the next few years. The work to be done includes the erection of a new power house, which will produce 500,000 h.p. of electrical energy, and the building of a tunnel seven miles long and 50 ft. in diameter. This tunnel will be some 200 ft. beneath the town of Niagara Falls.

To help with this work, Ontario "Hydro" requires about 2,000 British workmen, particularly tradesmen, such as carpenters, plumbers, welders, bulldozer drivers, high-voltage electricians, mechanics, fitters and riggers. They will be required to work for two years and in return for this "Hydro" will advance the successful applicants fare money from port of embarkation in England to Toronto. Upon arrival in Toronto, immigrants will spend a few days in one of the Commission's camps while awaiting dispersal to their allotted jobs. Wages are high in Canada and an unskilled labourer can earn at least £13 a week, while tradesmen's earnings are proportionately higher.

All those interested should apply in person or in writing to Ontario House, Charles II Street, London, S.W.1. In order that those who live far from London may have an opportunity to join in this immigration plan, the Ontario "Hydro" interviewers will visit the main cities and towns in the British Isles during the next few months.

India's Industry

PLANNED development of industry and agriculture as a means of raising living standards has been the keynote of Indian Government policy since the achievement of independence. In fact, of the Rs. 18,396 million development plan more than Rs. 6,000 million are to be spent on agriculture. It is in this programme that three multi-purpose projects are accorded high priority — the Damodar Valley (Rs. 500 million), Hirakud (Rs. 300 million) and Bhakra-Nangal (Rs. 757 million). All are now in an advanced stage of construction.

Australia's Demands

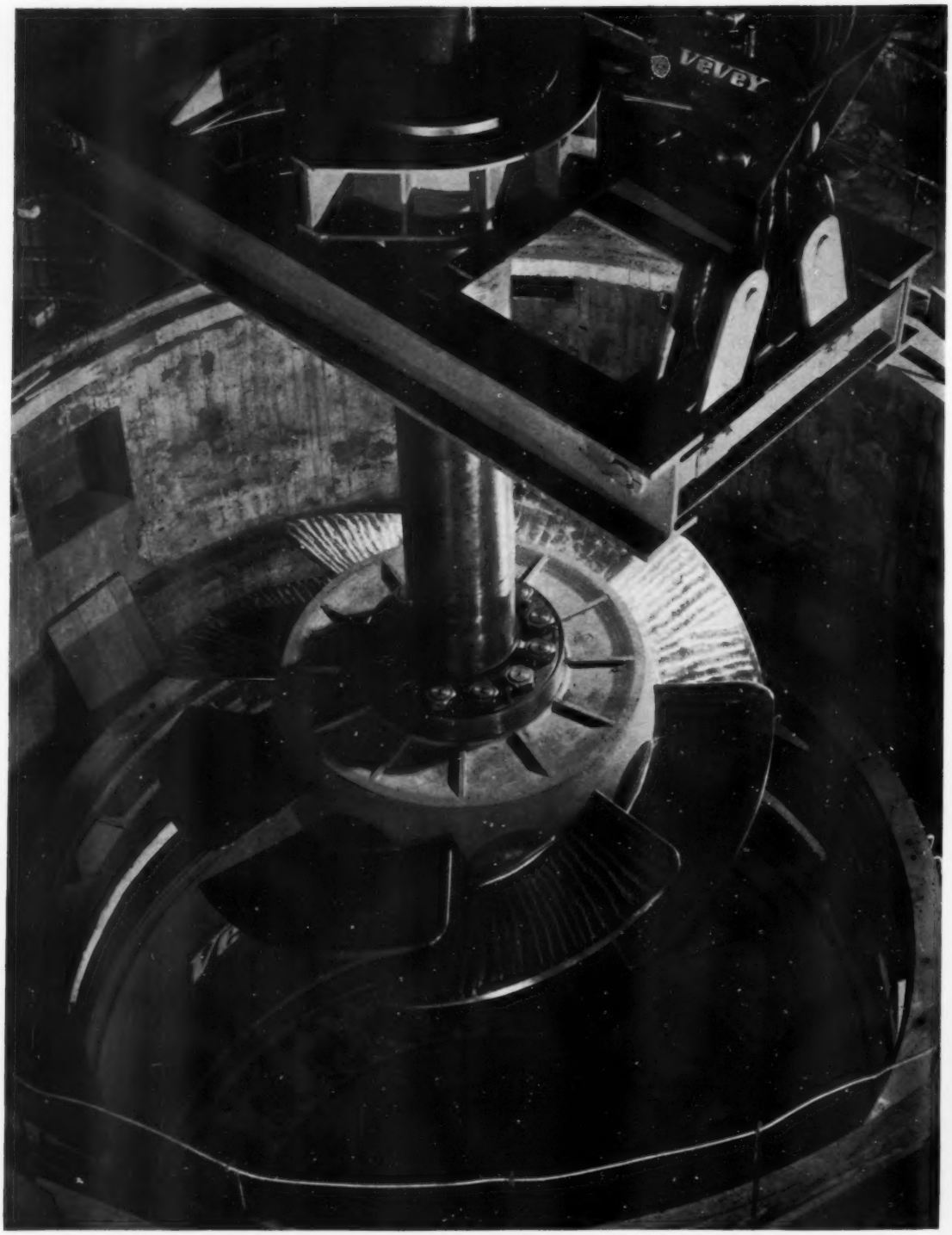
FREQUENT power blackouts in Sydney and other industrial parts of New South Wales have led to a big demand for private auxiliary generating plants. The blackouts are due to the inability of power houses to meet fully the rapid growth in the demand for electric power. An executive of one of the biggest manufacturers of auxiliary generating plant in New South Wales has estimated that one out of every three factories now has an auxiliary plant. At one time it was thought the market for such plants had been exhausted. The fact is, however, that it had scarcely been explored.

A Notable Exhibition

THE International Engineering Exhibition held recently in New Delhi drew record crowds, and in the first fortnight it was visited by more than 250,000 people. This, the first display of its kind in the East was organised by India's Central Board of Irrigation. Founded 23 years ago the board has to-day become the principal Indian body responsible for the pooling of irrigation and hydro-electric knowledge and experience, and its dissemination to engineers and technical organisations. The board also acts as the national committee for the International Commission on large dams and the newly established International Commission on Irrigation and Canals. It provides liaison with the World Power Conference and with the International Association of Hydraulic Research. Contacts for the exchange of literature have been established with more than 200 engineering and research bodies throughout the world. To encourage original research work the board has instituted a medal to be awarded annually for the best paper published on research or contribution to the development of water resources in the country.

Water Power in British Columbia

ACCORDING to the Vancouver correspondent of *The Times*, American Army engineers who have been exploring power possibilities in British Columbia, near the Columbia river, to relieve a threatened water shortage at the Grand Coulee dam in Washington State, have found a power site rivalling that of the Aluminium Company of Canada's project in Tweedsmuir Park. At a point on Big Bend highway, 90 miles north of Revelstoke, the Columbia can be stopped by a 600 ft. dam at the end of a canyon, producing, it is estimated, not less than 500,000 h.p. The proposed dam would be just below Mica Creek, near the town of Wardner, and would hold the Columbia river in storage for the drought seasons at Coulee dam, 300 miles south. The water would first be used by Canada and then by the United States.



Eight bladed Vevey Kaplan runner developing 33,500 h.p., 43 m. head, 214 r.p.m.

A New Swiss Low-Head Station

Our Special Correspondent describes the newly commissioned low-head underground hydro-electric station at Lavey, which started operating towards the end of 1950.

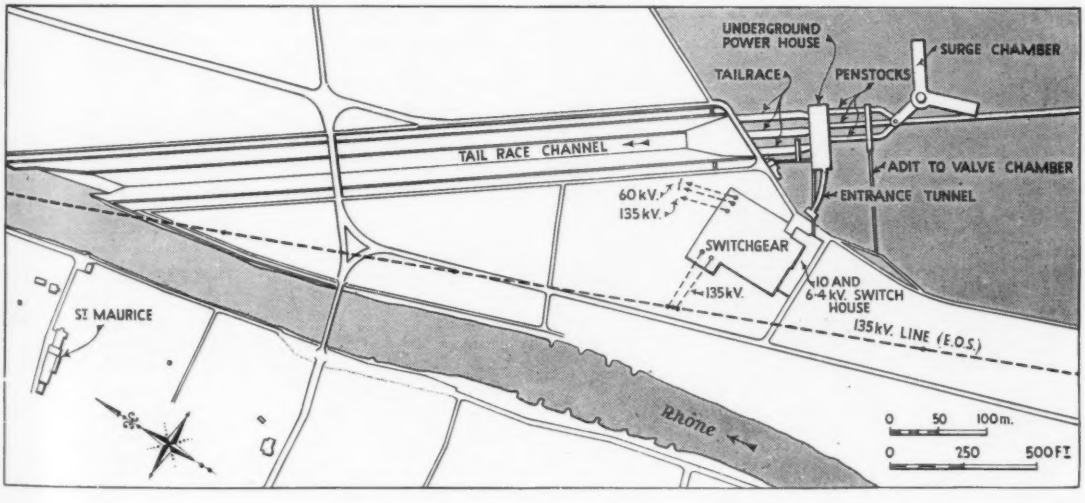
La première centrale souterraine de basse chute construite en Suisse est décrite çi-dessous. Située sur le Rhône, à Lavey, près de St. Maurice, elle remplace la station de Bois-Noir qui avait été installée dans ces parages au début du siècle. Avec une capacité finale de 100 000 hp la nouvelle centrale augmentera de près de 60 millions de kWh la capacité hivernale d'énergie disponible. Les alternateurs et la station extérieure de commutation, adaptée aux conditions très diverses du réseau suisse, offrent un intérêt tout particulier.

Se facilita una descripción de la primera central hidroeléctrica subterránea de salto bajo en Suiza. Está situada en Lavey, sobre el río Ródano, cerca de Sr. Maurice, y suplanta la central de Bois-Noir que fué construída en las cercanías a principios del siglo actual. La nueva central generadora de fuerza motriz, con una capacidad final de 100.000 H.P., aumentará la energía disponible en el invierno en 60 millones de kWh aproximadamente. El diseño de los alternadores despierta uninterés muy especial y la instalación distribuidora de alta tensión en el exterior es muy interesante debido a que permite trabajar bajo condiciones grandemente distintas, tal como son requeridas por la red suiza de transmisión de energía.

ALTHOUGH Switzerland has long been identified with the efficient development of her water resources and now enjoys a high production of energy, which allows the annual consumption of electricity, *per capita* of the population, to be one of the most impressive in the world, the State still has insufficient generating capacity to meet the increasing demand for power. Swiss industry needs more electricity if it is to contribute in larger measure to the national economy; domestic consumption, too, is rising, and to ease the situation a number of important hydro-electric projects are under construction.

Among the more interesting stations is the Lavey Hydro-Electric Station of the Lausanne City Electricity Supply, which recently went into service with one unit on load. When the station is completed the machine hall will contain three main alternators and an auxiliary set rated at 1,500 h.p., but at the end of the first development stage there will be only two main sets of 33,000 h.p. each. The Lavey station is designed to replace the older one at Bois-Noir near St. Maurice on the Rhone, which was built at the beginning of the century.

Fig. 1. Layout of underground power station, outdoor substation and tailrace



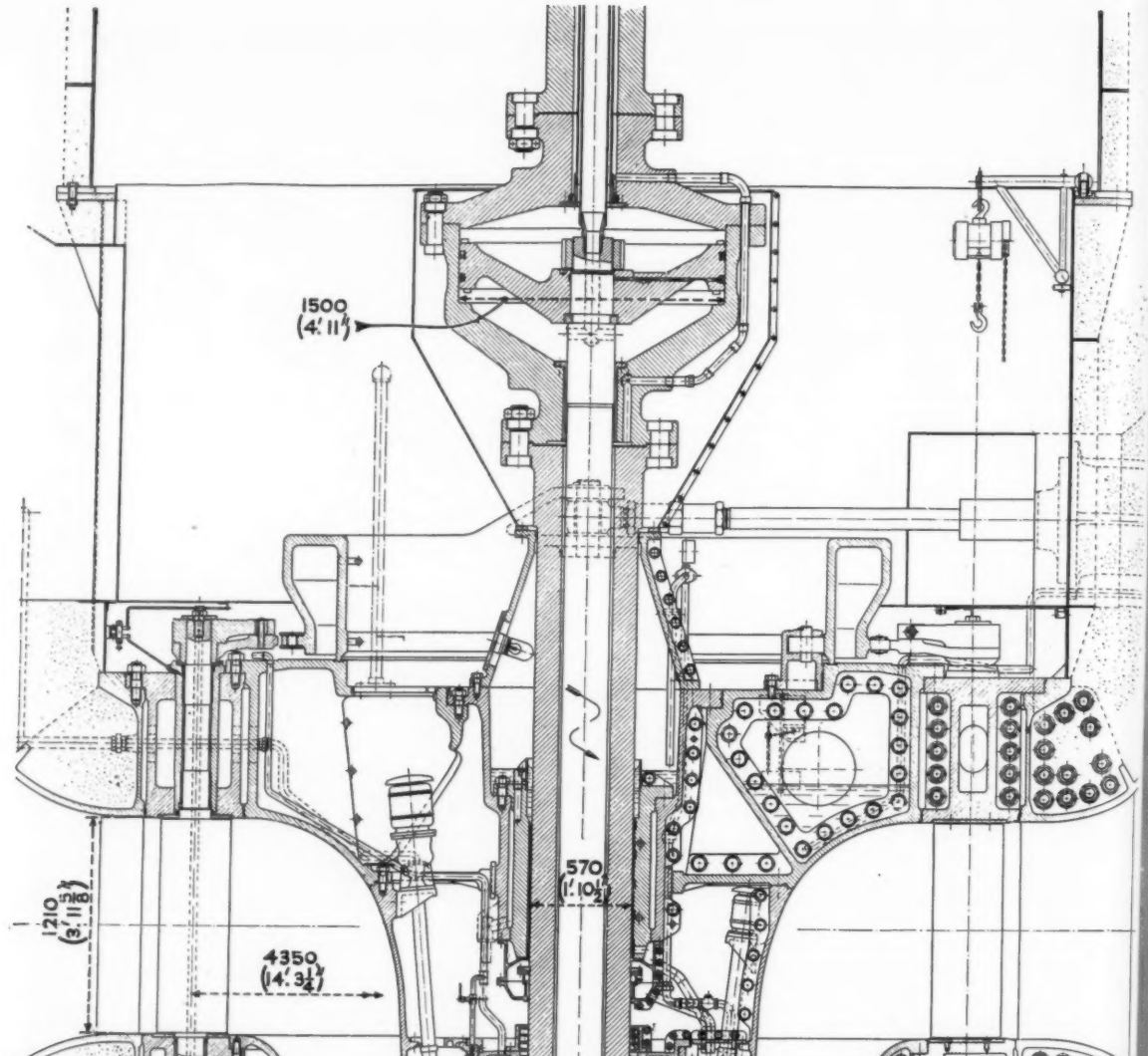


Fig. 2. Part section through Kaplan turbine

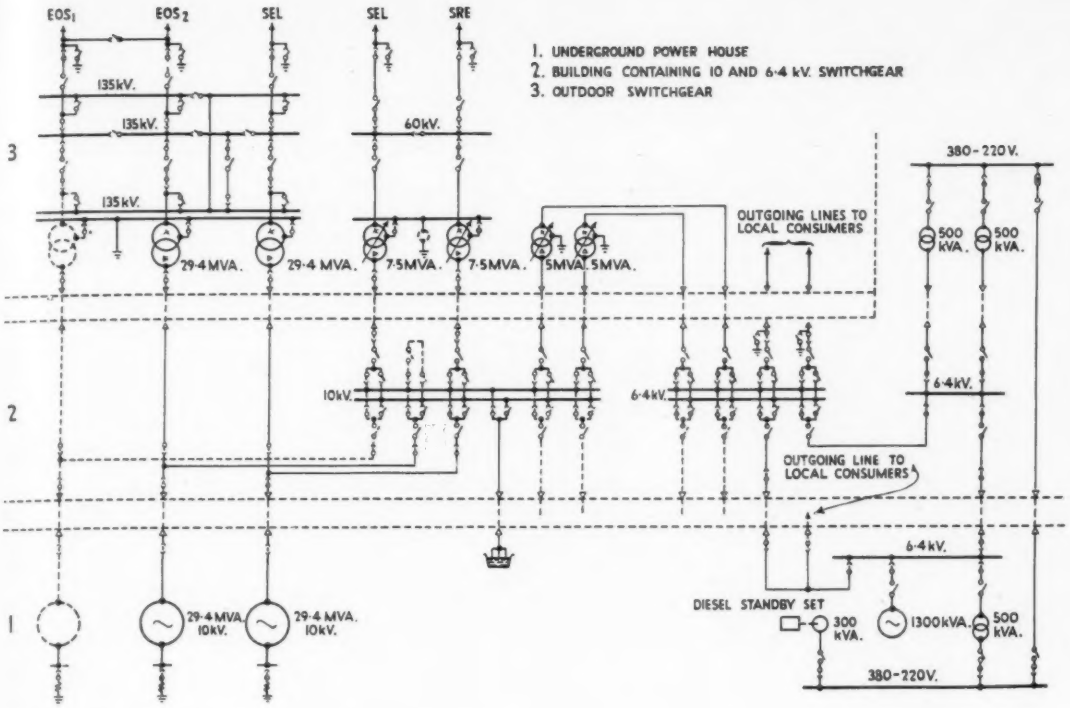


Fig. 3. Single pole diagram of Lavey power station

The annual energy production of the new station is estimated at:

First stage with two alternators:

Winter energy	-	98 million kWh
Summer energy	-	170 million kWh
Total - - -		268 million kWh

Complete station with three alternators:

Winter energy	-	98 million kWh
Summer energy	-	228 million kWh
Total - - -		326 million kWh

The old plant at Bois-Noir produced only 38.4 million kWh of energy during the winter months, so that the Lavey station, although operating under a low head of water, will make an important contribution to Swiss economy, since it increases the amount of energy available during winter by about 60 million kWh.

Station Site

The Lavey Station (Canton Vaud) is situated on the right bank of the Rhone and uses its waters which are carried through a tunnel to the underground power house excavated in living rock. This diversion allows an average head of 40 metres to be used before the water is returned by way of a tail race channel to the river: thus Lavey becomes the first Swiss low-head underground power station. When completed it will have a capacity of 100,000 h.p. A dam has been built on the Rhone at Evionnaz, about five kilometres upstream from the power station, and water is brought from it to the surge chamber deep in the rock by a tunnel 7.75 metres in diameter. From there it is taken

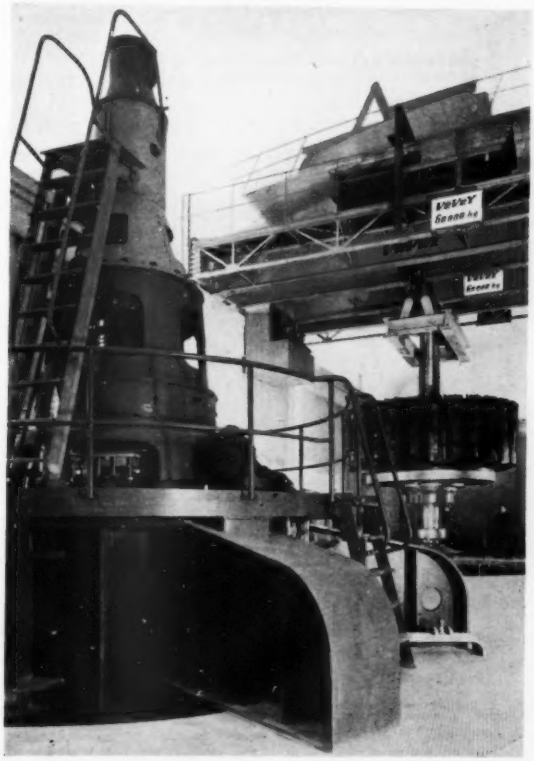


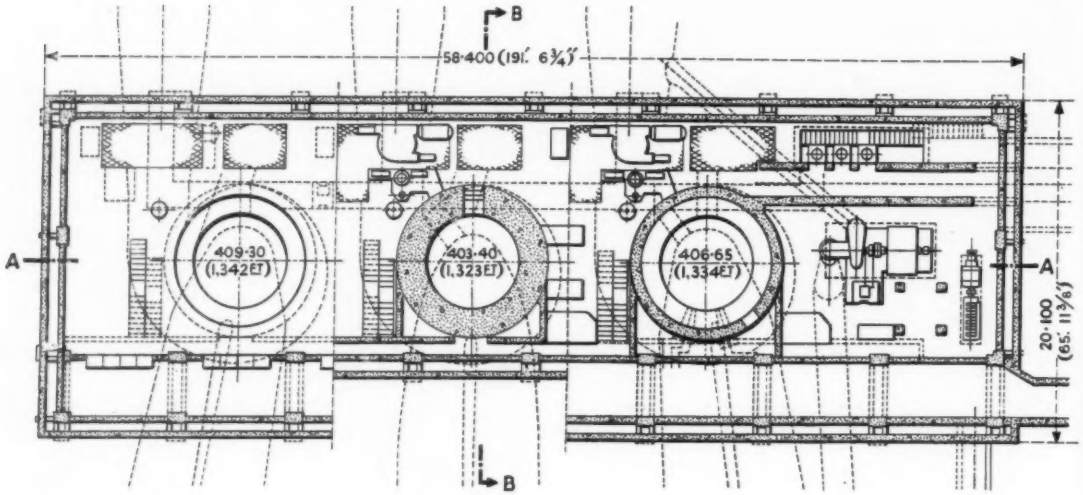
Fig. 4. Upper bearing bracket of Brown Boveri alternator showing auxiliary equipment mounted on main shaft extension

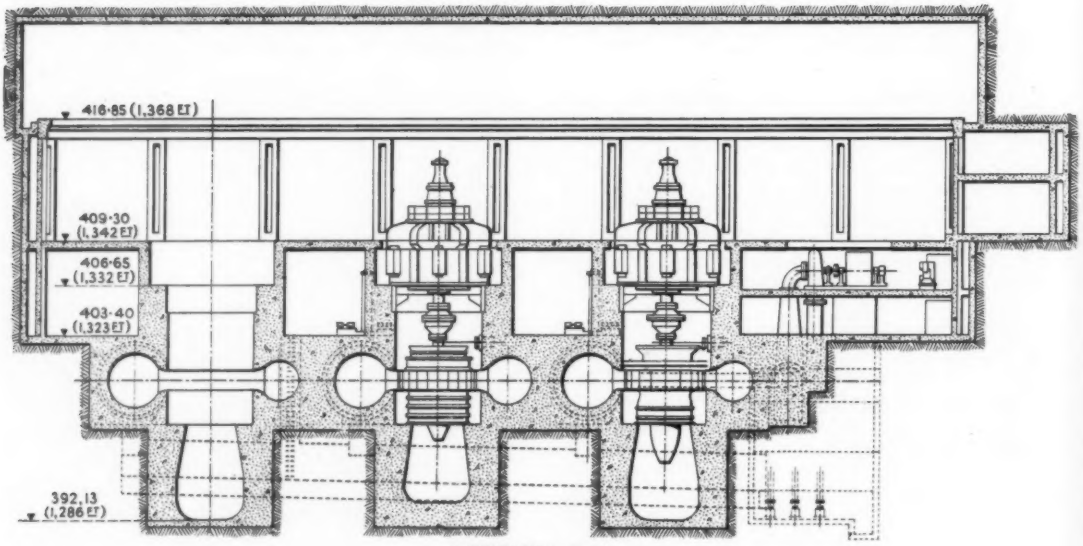
through three underground penstocks 75 metres in length and reinforced throughout by concrete to the machine hall, which is the most inspiring part of a magnificent constructional project.

The subterranean method of building was adopted for the power station because of the geological conditions obtaining in the Rhone Valley. The ground is mainly alluvial and would not be sufficiently stable for the erection of a power station on normal lines; special measures would have been necessary if there had been no alternative to outside construction, but they would have involved additional costs. Apart, however, from the financial aspect, there was the more important consideration of security in war-time and that gave force to the decision to build underground. The total cost of the station, including the preparatory work involved, is between 60 and 70 million Swiss francs; it is estimated that the subterranean method of construction led to an increase in the cost of about two million Swiss francs. The layout of the Lavey station is shown in Fig. 1.

Generating Sets

At this stage of development two of the three alternators, each rated at 29,400 kVA, are *in situ*, and the foundations for the third are ready for the set to be installed. The characteristics of the main alternators, two of which are the creations of Brown





SECTION A. A.

Figs. 5 and 6. Plan sectional elevation of underground power house; the turbines will have a total output of 100,000 h.p.

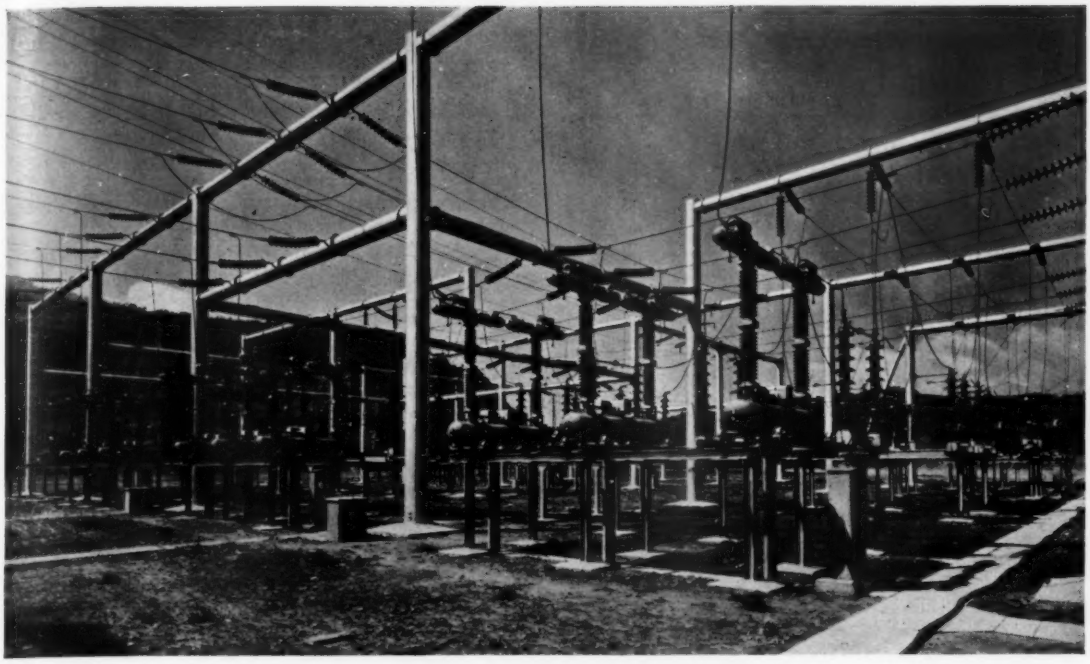
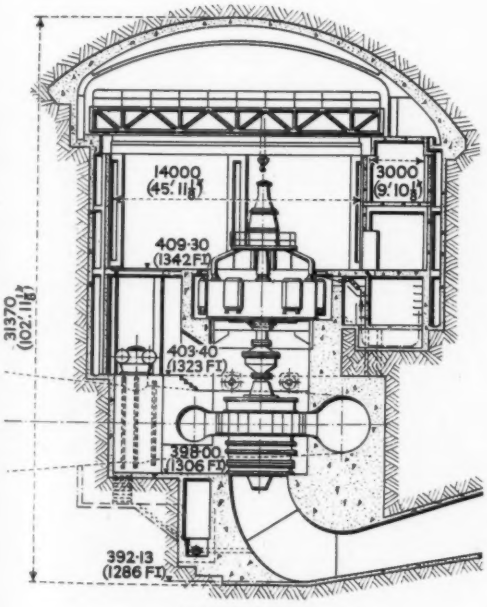


Fig. 7. Out-door high-voltage switching station. Note that equipment is raised above snow level

Boveri—an order for the third unit has yet to be placed, and will depend upon the running experience of those already installed—are as follows:—

Number of phases	-	3
Frequency	- -	50 c/s
kVA rating	- -	29,400 kVA at 0·8 p.f.
Output	- - -	23,500 kW
Line voltage	- -	10 kV ± 12%
Rated speed	- -	214 r.p.m.
Runaway speed	- -	500 r.p.m.
Flywheel effect	- -	1,450 tm²
Total weight	- -	235 t approx.
Weight of rotor	- -	115 t approx.



SECTION B.B.

Fig. 8. Transverse section through power house

One of the two alternators, both of which are of the vertical-shaft enclosed type with closed-circuit air-cooling and fitted with six water-cooled radiators mounted directly on the casing, is driven by a Kaplan turbine built by Chamilles S.A., Geneva, and the other by a Kaplan turbine constructed by the Ateliers de Constructions mécaniques S.A., Vevey (see Fig. 2).

Mounted on the shaft extensions are a main exciter of 187 kW, 240 V; an auxiliary exciter of 5 kW, 85 V, combined with an auxiliary alternator of 2 kVA, 110 V, 50 c/s for supplying the driving motor of the turbine governor. The efficiency obtained with these main alternators, including the exciter and guide bearing losses, but excluding the losses in the thrust bearing, at full load and with a power factor of 0·8, is over 97 per cent. At unity power factor it is over 98 per cent. Each alternator produces its full output of 29,400 kVA at a power factor of 0·8 within the voltage range between 10 kV ± 12 per cent. With under-excitation at a power factor of 0 and 80 per cent. of the rated voltage a purely reactive output of 17,000 kVar is obtained, and this is sufficient to enable one machine to energise the whole of the supply network without risk of self-excitation.

The alternators feed a 10 kV double busbar system and, through three main transformers, a 135 kV double busbar system (Fig. 3); three 135 kV overhead power lines are connected to the latter, one going direct to Lausanne and the other to the neighbouring system of the Energie de l'Ouest Suisse (E.O.S.).

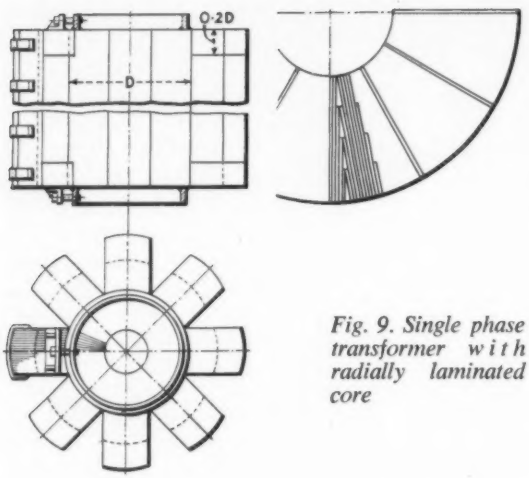


Fig. 9. Single phase transformer with radially laminated core

Three vertical-shaft main alternators each rated at 29,400 kVA, 214 r.p.m., coupled to 33,000 h.p. Kaplan turbines.

One horizontal-shaft auxiliary set of 1,300 kVA, 600 r.p.m., driven by a Francis turbine.

One stand-by set consisting of a Sulzer 350 h.p., 600 r.p.m. four-stroke Diesel engine coupled to a three-phase 300 kVA, 380/220 volt alternator; and the necessary equipment for starting up the plant and for regulation and protection of the machines.

Two 60-ton cranes traverse the machine hall, and by the insertion of a cross beam for 115 tons even the heaviest pieces of equipment can be lifted.

The 6·4 and 10 kV apparatus and the control room for the whole station are placed in a nearby building which, besides being architecturally attractive, has some excellent features in the manner of lay-out. The building also includes the dismantling tower for the transformers, the maintenance and repair workshops, the compressed air plant for the switching equipment.

Connected to the 10 kV busbars are two 7,500 kVA transformers with on-load tap-changing switches feeding two 60 kV overhead lines, and two 5,000 kVA transformers with on-load tap-changing switchgear supplying a 6·4 kV double busbar system, from which three 6·4 kV lines go out to the local load centres. In addition, the 6·4 kV busbars supply the power for the auxiliary equipment by means of two 500 kVA transformers. The installation could have been simplified by building the alternators for 6·4 kV and leaving out the 10 kV busbars altogether, but such a system was not employed because the cables between them and the transformers would have become much more expensive. In addition, the considerably higher short-circuit currents would have led to higher costs for the general equipment.

As it stands the circuit arrangement of the plant is notable for the high degree of flexibility obtained, and the installation will be able to fulfil without difficulty all the numerous demands made upon it during operation. Because the generating equipment of the power station is situated underground it has been necessary to place the main part of the switchgear separately.

When completed the underground section of the station will comprise (see Figs. 5, 6 and 8):—

Fig. 10. Spiral casing in course of erection on site

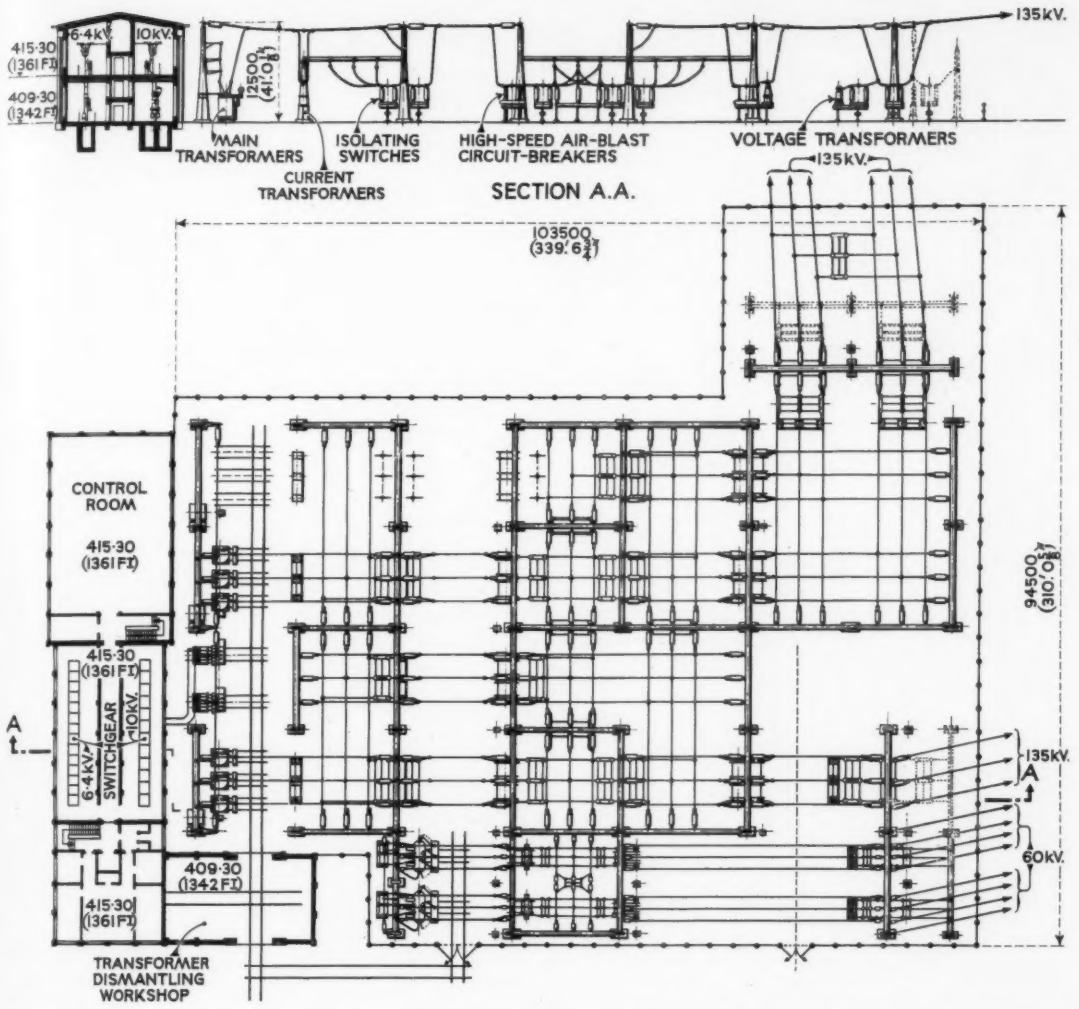


Fig. 11. Plan and sectional elevation of outdoor high-voltage switching station

stores, offices and staff rooms. Just outside lies the open-air high-voltage switching installation and transformers which connect the plant with the power transmission lines of the Lausanne City Electricity Supply and the neighbouring systems. In a pump house near the tail race are three vertical-shaft motor-driven pumps of 43 h.p. each which force ground water to a central tank, with a capacity of 300 cu. metres, for cooling purposes. The water flows by gravity to the alternator coolers, thrust bearings, main transformers, and other equipment, including the liquid resistance located next to the pump house.

The two Brown Boveri alternators are erected in such a way that only the upper bearing bracket and the exciters project above the floor of the machine hall. There are two guide bearings and the weight of the rotating part of the whole set is carried by the thrust bearing in the upper bearing bracket. The thrust and upper guide bearings were built by the turbine manufacturer, and both run in an oil bath which also forms the centre portion of the upper bearing bracket. The stator frame fits directly on to the top of the turbine tube ring, the upper section of which was supplied by Brown Boveri. This is already provided with six feet on which the lower bearing bracket rests, so that sole plates are dispensed with for the alternator.

The frame is in two sections, being fabricated from sheet steel plates and section iron and welded together; the dimensions of the material employed are, of course, such as to ensure adequate strength even under conditions of abnormal stress. Individual sections of stator laminations are separated from each other by spacers so as to leave cooling ducts; near the bore these spacers are arranged to follow the shape of the slots exactly. The slots thus form closed ducts along the whole of their length and there is no risk of the insulation bulging out into the ventilating ducts. The stator winding has two coils per slot; and in order to reduce losses the individual conductors are split up into separate sub-conductors, which are insulated from one another and so transposed that each of the sub-conductors takes up every position in the section of the coil conductor over the whole length of the slot.

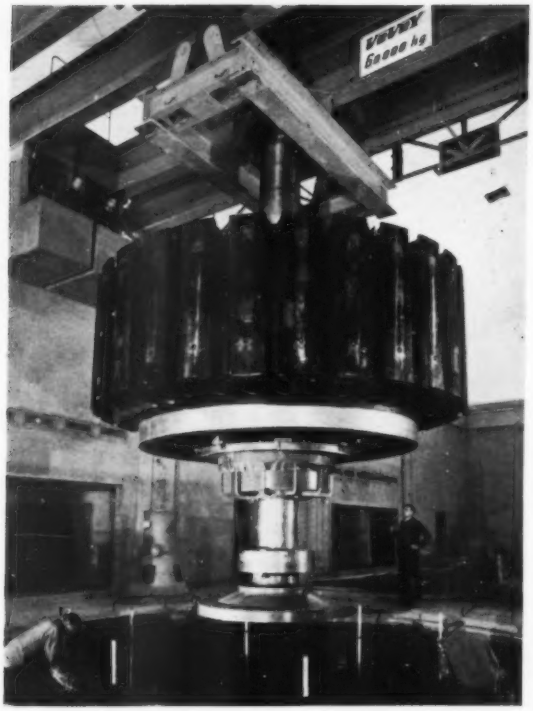


Fig. 12. Rotor of Brown Boveri alternator being lowered into position

Four cast-steel rings, shrunk on to an eight-armed spider, form the rim of the rotor; and into the outer face of it dovetail grooves are milled and used for fixing the poles. The torque is conveyed from the spider to the rim by means of bolts located half in the rim and half in the spider; these bolts also ensure perfect centring of the rim on the spider at the run-away speed (500 r.p.m.) In spite of the open stator slots, the relatively large air gap enabled solid poles of cast dynamo steel to be used—thus contributing to simplicity and strength of construction. The special form of the poles, which are set at an angle so as to avoid slot harmonics in the voltage curve, allows a voltage of sine-wave form to be induced in the stator windings. The alternator shaft is a single forging and has a bore through its centre to take the pressure oil pipes required for the regulation of the Kaplan runner blading.

Six I-girders are fixed to both the steel bearing brackets; those for the lower bracket being welded to the centre part, while those for the upper one are bolted on so that they could be removed for transport. The central part of the upper bracket incorporates the thrust and guide bearings; the considerable height of this bracket provides a high degree of rigidity, so that in spite of the heavy load to be carried the flexion of the structure is small and practically vibrationless. As a result of the star arrangement of the girders only deformations symmetrical to the machine shaft can arise so that all external conditions for satisfactory operation of the thrust bearings are fulfilled. Radial forces, such as occur during short-circuits, are taken up equally in all directions.

The lower guide bearing situated in the lower bearing bracket is self-lubricated and water-cooled, the rotation of the shaft alone sufficing to produce adequate oil circulation. Braking of the rotor is accomplished by six pairs of brake shoes with non-metallic linings, which are brought to bear on the inside and outside of a separate cast iron braking ring by means of compressed air operated plungers.

Main Transformers

Regulation of the voltage of the 135 kV lines is achieved by varying the voltage of the alternators between 8,800 and 11,200 volts. Each of the two alternators which have been installed during the first stage of construction feeds a 29,400 kVA bank of three single-phase water-cooled transformers. Details of these delta/star connected transformers are as follows :

Continuous rating - -	9,800 kVA
No-load transformation ratio	11,200/160,000 : $\sqrt{3}$ V
Weight, without oil - -	19,000 kg approx.
Weight, with oil - - -	23,300 kg approx.
Dimensions: Length - -	3,000 mm
Breadth - -	2,300 mm
Height, including bushings -	5,100 mm

The magnetic circuit of the transformers, which are a variation of the shell type successfully employed in recent years for large transformers, is formed by a core with radial laminations combined with U-shaped yokes fixed to the periphery of the core (see Fig. 9). Windings comprise cylindrical coils with paper-insulated copper conductors. The high-voltage winding lies between the two halves of the low-voltage winding, and is insulated by an oil-impregnated paper cylinder which is splayed at the two ends of the limb to form flanges. The whole is mounted in a cylindrical tank fitting closely around the active part, and thus requires much less oil than the normal type of transformer.

The advantages of single-phase radially-laminated units over the conventional type of three-phase transformer with a single tank are analysed by Brown Boveri, who supplied the electrical equipment for the Lavey station, in the following terms :

1. The height of the horizontal portion of the yoke is smaller than with any other type of core. This results in a considerable reduction in the height of the transformer, a reduction in weight, and far easier transport.
2. The shorter magnetic circuit leads both to a reduction in weight and in iron losses.
3. The shape of the core enables a circular tank to be employed, so that unused space is eliminated and the quantity of oil considerably reduced.
4. The radially laminated transformer is very quiet in operation and hum is negligible.
5. The use of single-phase transformers makes it easily possible to keep one unit, *i.e.* one-third of the capacity of one bank, in reserve. When such a spare unit is installed supply interruptions can be eliminated in the minimum of time.
6. Single-phase radially-laminated transformers are so small in dimensions that they can readily be transported completely assembled and also erected and commissioned rapidly.
7. Overhauls require less time, not only because of the reduced weight, but because of the simple internal construction.

As regards cost the set of three single-phase units is rather more expensive than an equivalent three-phase transformer; however, the much lower weight and smaller dimensions brought such a reduction in the costs of the assembly tower and crane that the whole transformer installation was found to be cheaper. This comparison does not take into consideration the fact that a single-phase stand-by transformer is cheaper than a three-phase unit and requires less space, while the changing over and checking of a single-phase unit is also easier and can be carried out much more quickly.

The severe operating conditions have led to an apparently complicated electrical scheme for the outdoor switchgear station, which is illustrated in Fig. 11. The photograph on page 49 shows that all the equipment is placed on high frames so that it remains above the snow level in winter and can always be safely inspected on foot. This arrangement requires a relatively large amount of space, but it results in a layout which is easy to supervise.

Elaborate equipment for the protection, voltage regulation and automatic synchronisation of the plant has been provided; and because of the general employment of compressed air for the circuit-breakers, voltage transformers, and remote controls the layout of the compressed air plant was given particular care to ensure absolute reliability. Compressed air is distributed through a ring main system so that all equipment can be fed from two sides.

On its completion Lavey will be the first Swiss low-head underground power station; the machines have been adapted to the peculiar problems of subterranean installation, and the switchgear allows of widely different operating conditions entailed by the large number of transmission lines which come together in the vicinity. The power station includes many innovations which have led to greater reliability and increased economy and which have been achieved through the use of modern methods and materials. It is thus in many respects a pioneer plant.

Book Reviews

Air Compressors; Control and Installation.

By P. C. Bevis. Published by Sir Isaac Pitman & Sons Limited, Pitman House, Parker Street, Kingsway, London, W.C.2. 1950. 8⅝ in. × 5½ in. × ⅝ in. 192 pp., with index. 87 ff. Price 20s. net. Some significance attaches to the fact that air compression, at one time considered to be adequately dealt with in a chapter or two of a general textbook, has at last the distinction of being treated in a separate volume. Compressed air used in industrial applications is expensive stuff and its generation, transmission and economy of usage deserve close attention. The author has had a lifetime of experience in handling air-compression problems and his book is valuable in the attention it draws to those points in the overall installation of a plant which lead to trouble-free service and high efficiency. The control accessories are thus discussed in detail and special attention is given to governing technique which is not as simple as it would appear.

The various chapters cover automatic governing gear, the application of automatic stop and start control gear, air receivers, aftercoolers, intake filters and silencers, cooling systems, delivery filters, foundations and air mains. Problems of cooling, moisture separation and pipelines are adequately handled, together with a host of other matters which are not always appreciated in the rough and tumble of practical operations. An appendix gives a number of useful tables relating to the compression and transmission of compressed air and there is a competent index. The illustrations throughout are excellent.

Estatística das Instalaçoes electricas em Portugal

(Statistics of Electric Installations in Portugal). Published by the Portuguese Ministry of Economy, Directorate of Electric Services, Lisbon, 1948. 10¾ in. by 7 in., 435 pp. This volume gives a complete list of the electric power generating and other installations in operation in Portugal, with fairly comprehensive particulars. The installations are divided into public-utility plants and plants in private ownership. The hydro-electric installations are listed on pp. 2 to 28 (public), and 74 to 93 (private). Detailed figures of energy consumption and other particulars are given for each district separately on pp. 200 to 400, together with fairly full information on the boiler plant, prime movers and generators employed. In the hydro-electric section the type of turbine is given, the name of its maker, the operating head and appropriate details of the generating and transforming equipment.

Surface Water Supply of Canada (St. Lawrence and Southern Hudson Bay Drainage; Ontario and Quebec) for the Climatic Years 1945-47. Bulletin 99.

Published by Department of Resources and Development of Canada, Water Resources Division. Printed by Edmund Cloutier, C.M.G., B.A., L.Ph., Ottawa. Price one dollar. This report presents the results of extensive hydrometric investigations in Ontario and Quebec, the data being arranged on a river-basin basis. Previous reports, covering Ontario, were prepared by the Hydro-Electric Power Commission but date back to 1912-19, and the present report gives data for the entire province with the exception of the Winnipeg River and its tributaries for the two years ended September 30, 1946 and 1947. Particulars of the Winnipeg River were given in Water Resources Paper No. 97 under the title "Arctic and Western Hudson Bay Drainage" and relate to the years 1920 to 1945.

The collection on a Federal basis of hydrometric data for Quebec dates from 1922 when an agreement was reached between the Quebec Streams Commission and the then Department of the Interior. In addition to the data relating to the two climatic years ended September 1947 the present report also tabulates previous records at certain stations, secured through the co-operation of various organisations.

The report contains some 400 pages and gives the location of the measuring point, the drainage area, the extremes recorded, and tables showing the monthly and daily discharge rates.

Fig. 1. Double circuit 132kV overhead transmission line from Shira to Inveruglas with one circuit only ; this line was erected for the North of Scotland Hydro-Electric Board

H.V. Transmission

The author discusses electrical and mechanical problems following the need to transmit larger blocks of power over longer distances as a result of the economic development of hydro-electricity, and outlines the latest practice in overhead H.V. transmission.

By N. G. SIMPSON, A.C.G.I., M.I.E.E., A.M.I.C.E.

L'importance du transport de courant à haute tension croît avec le développement de l'industrie hydro-électrique; en effet, les centrales génératrices sont souvent situées très loin des centres industriels de consommation. Les problèmes immédiats sont essentiellement des problèmes d'électricité. Il s'agit, en bref, d'éliminer dans une large mesure les pertes par effet de couronne et le brouillage radio-électrique des conducteurs et de résoudre les difficultés additionnelles d'isolement, de commutation et de protection des circuits. L'article çi-dessous traite de ces questions.

La intensificación de desarrollos hidroeléctricos ha aumentado el interés de las transmisiones de alto voltaje debido a que las centrales generadoras de fuerza motriz muy frecuentemente están situadas a grandes distancias de los distritos industriales donde se consume la energía eléctrica. Los problemas inmediatos son esencialmente eléctricos. En breves palabras, están relacionados con la adopción de conductores razonablemente libres de pérdidas de corona y de interferencia de radio, a los cuales tienen que añadirse los problemas suplementarios de aislamiento y coordinación de aislamiento, distribución y protección del circuito. Estos factores son discutidos en el artículo que se reproduce a continuación.

TO those specially interested in electricity supply, the past year will be especially remembered by the occurrence of both the Conference on High Tension Systems (C.I.G.R.E.) in Paris and the World Power Conference in London.

Now that they are concluded, those who were privileged to attend them will, above all else, be impressed by the large increase in actual and projected water-power schemes of the world, and the indirect influence they had on the papers and reports relating to H.V. Transmission.

Some measure of the expansion of hydro-electric power schemes can be obtained by dipping at random into the interesting statistics given in the World Power Conference papers. It will be seen, for example, that the United States has an installed capacity of 16½ million kW, which is three times that installed in 1920. In India, although the existing installed capacity is only ½ million kW the projected capacity in the next few years is just under 6 million kW. There is admittedly 70 per cent. more thermal generating plant than water in India at present, but the greater proportion of the future expansion will be water power. The figures for Sweden are also impressive; in 1948, just under 3 million kW were installed, in 1949, however, 2½ times as much again was under construction.

Many similar examples are available, all of which show the continued trend towards electricity generation in large blocks of power, many of them produced at remote distances from the points of consumption. There are varied reasons for this, the most important of which is probably the increased cost of thermal generation coupled with the desire of many countries to be free of the importation of coal and oil, especially when large hydro-electric resources are available. In many cases, hydro-electric schemes are subordinate to bigger projects for irrigation, the whole being stimulated by the present world tendency to develop and improve the social well-being of backward areas.

Although the world resources for hydro power are enormous (just under 6 thousand million kW) a small

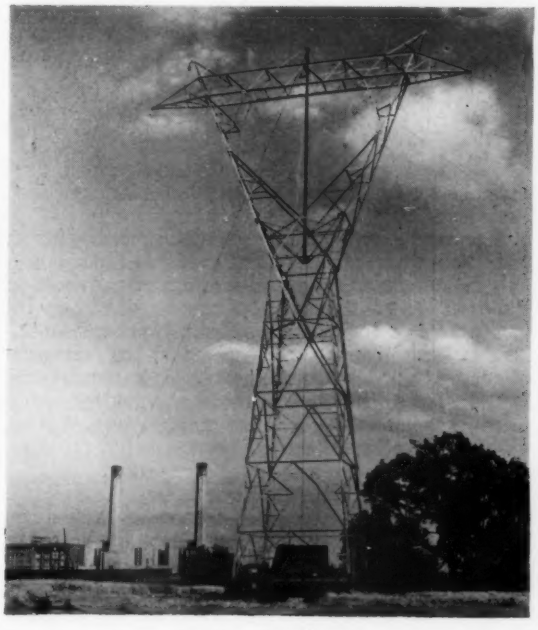
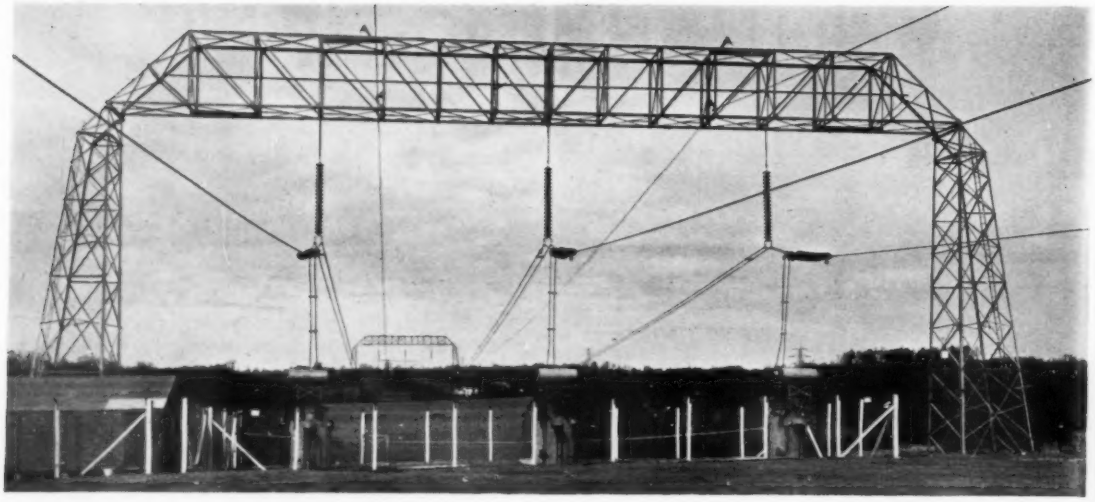


Fig. 2. The first tower of the first section of the 275 kV super grid line between Staythorpe and Barnby Moor which is being erected for the B.E.A. by British Insulated Callender's Construction Co. Ltd.



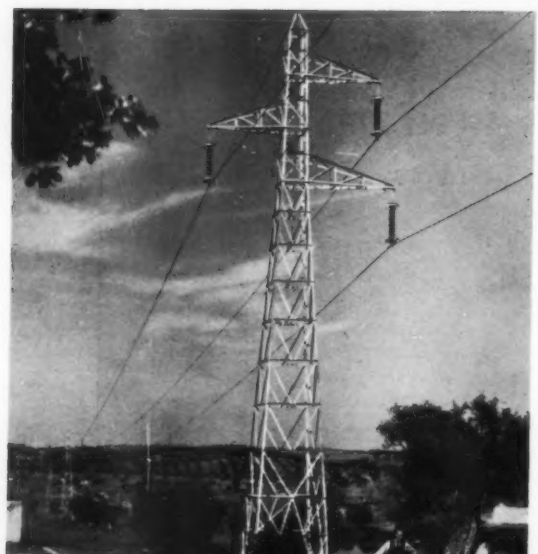


Fig. 3 (above). H.V. test line, Leatherhead, showing terminal gantry and 275 kV transformer compound
Fig. 4 (left). General view of transmission line carried by intermediate type towers, Zezere—Lisbon

proportion only of this can justifiably be developed, and in most cases the resulting available capacity can only be suitably deployed with an accompanying and elaborate H.V. transmission system. To help to justify large power generation in remote places, stimulus has been given in recent years to the formation of nearby basic load consuming plants to increase the load factor. An example of this is the modern use of thermo compression or heat pump plants for industrial evaporation in connection with fertiliser, cellulose, aluminium and sugar production.

It is also very obvious that increased hydro-electric development has caused a corresponding activity in the H.V. transmission world, by reason of the recurring demand that greater power shall be conveyed over longer distances. The immediate and urgent problems are without question electrical ones, emerging from the inevitable increase in working voltage, in fact, electrical engineers have been particularly active on these problems during the last few years, and the C.I.G.R.E. papers of 1950 reflect in large measure the experiments and investigations which have taken place.

Briefly, it is necessary to provide conductors which shall be reasonably free from corona loss and radio interference. The inductive reactance of the electrical circuits shall also be reduced as much as possible in the interests of voltage drop and circuit stability, and the large wattless kVA component of the transmission circuit shall be either compensated or reduced in the interests of efficient operation. There are of course supplementary but no less important problems of insulation and insulation coordination, switching and circuit protection which also have to be carefully considered and resolved.

Many years ago in America experiments were carried out on multiple or bundle conductors for use on A.C. high voltage overhead circuits to reduce corona loss and circuit reactance. During the early part of the second world war, the Germans turned their attention to this idea when considering their plan for a European Grid, which involved the use of a standard transmission voltage of 400 kV. Their studies and experiments were advanced to the stage where the designs for the transmission lines were almost completed[2]. No construction, however, was ever carried out.

At the close of the war, the demand for more electric power throughout the world focussed world-wide attention to these problems, as a result of which H.V. outdoor experimental establishments were installed in France, America, and more recently at the British Electricity Authority's experimental establishment at Leatherhead, to study principally the electrical aspects of insulators and conductors of varied types and spacing under A.C. voltage up to 500 kV.

The world's largest existing transmission line is that associated with the Boulder Dam in America, where 240 MW is transmitted at 287 kV over a distance of 270 miles. The conductor is of the single hollow type made up of segmental copper, the overall diameter of which is 1.4 in. There are a number of lines in the world operating at 220 kV, but the majority of trunk transmission lines are at present operating at voltages under 150 kV.

The standard Grid transmission voltage in Great Britain is 132,000 although a super Grid is about to be imposed, the nominal voltage of which is 275 kV, but the operating voltage will actually reach 300 kV. The first towers are now in course of construction.

While the conductors for the British 132 kV Grid are for the most part 0.175 sq. in. equivalent copper S.C.A. each phase of the initial 275 kV lines will consist of twin 0.175 sq. in. S.C.A. conductors spaced 8 in. apart.

A further example of recent construction connected with hydro-electric power is that of a 70 mile 150 kV transmission line from Zezere (adjoining Castelo do Bode H.E. Station) to Lisbon in Portugal. The conductor is in this case a British standard 0.25 sq. in. copper equivalent section steel-cored aluminium type.

Generally speaking, it may be stated that conductors for working voltages up to approximately 200 kV in normal locations may consist of single stranded conductors. For working voltages above say 250 kV careful consideration must, however, be given to the economic limitation of corona losses (in relation to the location and climate), the extent, if any, to which the circuit voltage may ultimately be increased, the extent to which advantage may have to be taken of the substantial increase in load capacity inherent in the use of multiple conductors, and the influence of all these on the cost per kVA of load transmitted. In other words, it is impossible to generalise by saying that one or another type of conductor is appropriate for a certain working voltage. Nevertheless recent electrical research and investigations have done much to assist engineers to decide with precision the type and size of conductors for specific cases.

There is one important and inescapable conclusion to be drawn from the recent C.I.G.R.E. Conference—that higher voltages, up to and possibly exceeding 400 kV, will be used in the near future. The transmission line-designers and constructors of the world will, in their turn, be presented with formidable structural problems and responsibilities. Conductors of much greater size and complication will be suspended at greater spacings over greater distances which, by virtue of their importance, must be more than ever free from mechanical failure. It must be remembered that these overhead H.V. circuits, carrying two or three hundred megawatts each, are in many ways more important than the generators and transformers attached to them, since there can seldom be spare circuits and they are moreover often subject to the relentless deterioration from severe climatic conditions.

It has been mentioned that there has been a great deal of recent electrical research on this subject. It may be questioned as to whether there has been a corresponding or sufficient amount of research and development in the structural field successfully to overcome the resulting mechanical problems and, what is more important, to meet adequately the responsibility of providing the best possible value for the vast expenditure that will be incurred in the next ten years.

As an important and basic example, the design of overhead transmission lines in all countries should be based on national regulations, which should contain only those rulings which have a direct bearing on public safety. It is probably true to say however, that many of the regulations in existence are obsolete and unnecessarily elaborate, containing as they do detailed instructions on matters upon which there is, and should be, a natural design latitude and flexibility.

The existing British Overhead Line Regulations have at least a great advantage in being brief and comprising minimum basic design conditions. However, a short time ago an I.E.E. Committee was set up to examine them with a view to recommending revisions and rationalisations as necessary.

The resulting deliberations are clearly set out and explained in a recent I.E.E. paper[3], and they will no doubt be issued shortly. There is one feature of them which is almost revolutionary and which may contribute much to a correct and uniform international approach to the design basis of all transmission lines, especially the H.V. types under discussion. The theory was sponsored to a large extent by an I.E.E. paper[4] some years ago, and deals specifically with the treatment of conductor design loading which in reality, of course, consists of wind and ice. Briefly the important characteristic of a suspended conductor is that a specified load acting at an intermediate tension is by no means a direct indication of what it will support at ultimate or collapsing tension. In actual practice, the basis of design for nearly all overhead conductors is in the form of an arbitrary ice and wind load at an intermediate tension which usually corresponds to a "factor of safety" of 2.0. Recent views have quite rightly postulated that a realistic view should now be taken, and that first and foremost in any regulation for transmission line design, a load should be determined (from conditions of climatic severity, frequency, and general economics) above which the conductor should be allowed to break. The resulting mechanical design of insulators, supporting structures and foundations should be co-ordinated from this fundamental design condition.

More details are available in the references quoted below, but sufficient has been said to indicate a more rational approach to overhead line design and which has the additional advantage of providing a common international language for this important structural problem. Other matters, such as conductor vibration, foundation and structural economics are equally important, but subordinate to this over-riding conception of conductor design and structural coordination. Investigations and research on any of these, and other structural aspects, can then have a uniform aim which will ultimately be productive of both economy and trouble-free operation.

The author takes this opportunity of thanking British Insulated Callender's Construction Company Limited for permission to publish the above article and photographs.

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Hydro-Electric Power in the Union of South Africa

In providing accurate information about the hydro-electric potentialities in all parts of the world it is inevitable that we should have to touch on regions where those potentialities are very small. In this article D. F. Kokot, D.Sc., Chief Planning Engineer, Department of Irrigation, South Africa, discusses the position in the Union.

SOUTH AFRICA suffers from an exceedingly uncertain and erratic rainfall, characterised, moreover, by a bad seasonal distribution. The erratic nature of the rainfall is well illustrated by the annual rainfall figures for Jacobsdal, a station situated within the inland plateau at an elevation of 4,000 ft. above sea level. (Table I.)

TABLE I

Year	Rainfall Inches	Year	Rainfall Inches	Year	Rainfall Inches
1887	19.7	1907	17.6	1927	12.5
1888	17.3	1908	10.5	1928	14.0
1889	18.2	1909	17.0	1929	15.1
1890	22.7	1910	9.8	1930	10.9
1891	30.1	1911	15.5	1931	16.0
1892	15.5	1912	8.4	1932	8.9
1893	16.4	1913	10.6	1933	9.1
1894	20.2	1914	13.7	1934	21.0
1895	18.9	1915	9.8	1935	14.1
1896	18.4	1916	7.1	1936	15.8
1897	18.4	1917	17.0	1937	13.2
1898	28.6	1918	19.1	1938	13.2
1899	24.0	1919	8.4	1939	14.6
1900	17.3	1920	21.0	1940	9.9
1901	22.9	1921	14.9	1941	16.8
1902	19.8	1922	6.3	1942	17.8
1903	11.4	1923	11.9	1943	23.5
1904	16.9	1924	23.8	1944	10.1
1905	12.8	1925	17.9	1945	5.5
1906	17.6	1926	8.7	1946	15.0

Mean: 15.6 inches.

Even where the total annual rainfall is reasonably adequate its bad seasonal distribution presents serious difficulties both to the pastoral farmer, dependent on the rainfall only, and the irrigator who tries to supplement the rainfall by using the flow of the rivers on his crops. The marked seasonal distribution is shown in Table II.

TABLE II

Percentage of the area of the Union (col. 1) over which precipitation for the six months October to March, expressed as a percentage of the total rainfall for the year equals or exceeds the figure in col. 2.

Percentage Area of Union	Percentage of the Annual Rainfall
4.7	90
24.3	85
40.9	80
66.6	70
81.1	60
85.8	50
90.2	40
93.2	30
97.8	20

This table shows that the Union is sharply divided into summer and winter rainfall areas. Two-thirds of the country receives 70 per cent. or more of its total annual rainfall during the six summer months of October to March. The winter rainfall area, namely the south-western tip of the continent, is relatively small. It receives the bulk of its rain from April to August.

As can be expected from the erratic nature of the rainfall from season to season, and its marked concentration in a portion of the year only, the flow of the rivers is even more erratic, and truly perennial rivers of any size can be counted on the fingers of one hand. Even the Orange River, draining nearly half of the country, has been known to stop flowing altogether. Over a long period of gaugings it has been found that 77 per cent. of its total flow occurs from October to March. The average flow for the month of July is only slightly over one per cent. of the average flow of the year. The total run-off for a whole season has been as low as 18 per cent. of the long-term mean, and it has been as high as two and a half times the mean.

Even in excellent rivers which have never been known to stop flowing altogether the flow still remains very erratic. In the Komati River, which is probably the best one in South Africa so far as regularity of flow is concerned, we still find that 73 per cent. of the total annual run-off occurs during October to March, and that the maximum annual run-off is over four times the mean, and the minimum only one-third of the mean.

The position on other rivers is generally worse; in a large number of them, rising in the summer rainfall area, the flow during the late winter and spring frequently drops to a negligible amount or even nil. In the winter rainfall area the river flows are generally very low during the middle of the summer.

When it comes to the utilisation of river flow its erratic nature presents grave problems in every direction. In the development of hydro-electric power one is faced with the serious position that in many rivers the minimum flow is nil, and even in the better ones it falls to a dangerously low figure. To illustrate the point the Komati River was selected as an actual example of one of the most regular rivers in the Union. For calculation purposes it was assumed that a 50 ft. head could be made available. For a station based on a mean daily flow of 400 cusecs, but provided with pondage so that during part of the day up to 600 cusecs could be utilised, we have the following position: A station rated at 1,900 kW would be capable of producing 10.8 million kWh of electricity per annum if adequate water were available all the time. From a 33 year record of flow of the

river it is found that on an average the annual output would be only 8.6 million, leaving a deficiency of 2.2 million kWh. But in a bad season the output for a year would be only 5.9 million, leaving a deficiency of 4.9 million kWh. But during part of a bad season the flow drops as low as 5 per cent. of the required amount. This means that to produce power continuously an auxiliary thermal station would be required of a capacity equal to that of the hydro station. This thermal station would have to provide the mean annual deficiency of 2.2 million kWh, also an occasional deficiency up to 4.9 million kWh in a bad year. The advantage of such an arrangement would be the saving of coal on 8.6 million kWh per annum. The disadvantages would be: the additional capital cost of providing an auxiliary thermal station, the possibility of siting the station unfavourably in relation to coal supplies, and the possibility of siting the station unfavourably in relation to power demands.

Instead of building an auxiliary thermal station to supply power when the river flow fails it would of course be possible to stabilise the flow of the river by means of a storage dam. Analysis of the flow has revealed that in that way a steady flow of 400 cusecs could be maintained continuously, but the cost of the storage dam would be many times greater than the cost of the thermal station plus the capitalised cost of the coal needed to drive it.

The Orange River, which contributes roughly one-third of the entire run-off of the Union, is even more disappointing than the Komati. This is shown in Table III giving the flow conditions as gauged over a period of 24 years.

TABLE III

Flow in cusecs	Percentage of time when flow in Col. 1 was equalled or exceeded
1	99.5
5	99.4
10	99.3
50	98.8
100	96.0
250	91.6
500	84.2
1000	72.4
2000	59.3
5000	44.6

The Orange River has, however, one great merit from the power development point of view, namely that it has the Aughrabies Falls where at least 450 ft. of head could be utilised. By building a hydro station based on a mean daily flow of 5,000 cusecs, but providing pondage and installing plant capable of using up to 7,500 cusecs during peak hours, we should have the following position:

Maximum possible annual output	...	1,200 million kWh
Actual average annual output	...	743 " "
Average annual deficiency	...	477 " "

In a bad season, however, such as 1932-33, the actual output for the year would have been only 282 million units, with a spell of nearly five months with practically no flow in the river at all. To ensure continous power a thermal station, equal in capacity to the hydro station, would have to be built; or alternatively, storage would have to be provided to stabilise the flow of the river. Either of these alternatives would cost roughly £6,000,000. With storage it would be possible to draw off a steady 5,000 cusecs and it would result in an annual saving on coal to the extent of £1,000,000—at the price at which coal could be delivered at the Falls, some 800 miles by rail from the nearest coalfield. But obviously if a thermal station of this size were to be built it would be much more effectively sited nearer to the coalfields, and incidentally much nearer to the most important industrial centres with a large demand for power, where coal might cost less than one-quarter of what it would cost at the Falls and where power is to-day being produced at a cost of one-sixth to one-ninth of a penny per kWh. The Aughrabies Falls are situated in an extremely arid and very sparsely populated region with no present demand for power, nor can one at this moment foresee any appreciable demand, within any reasonable distance from the area, even in the distant future.

There is one important aspect of the problem of using water to generate power which probably overshadows everything else. In practically every part of the country, with its low and badly distributed rainfall, water is the final limiting factor in future development. In many areas both pastoral and agricultural development have reached their limits under the natural rainfall only. Only by irrigation can these areas be keyed to higher production, and in many parts of the country vast areas of potentionally productive soil must remain undeveloped and barren because there is insufficient water to irrigate all the land. Future industrial development, too, is rigidly limited by the quantity of water that can be made available. In this case, however, greater cost can be incurred in piping water over considerable distances, but a stage will nevertheless be reached when the cost of water will be so high as to discourage manufacturers who require large quantities of it. This scarcity and the need to reserve its use for those purposes which cannot do without water leads one to the conclusion that power should be obtained not from water but from coal of which, fortunately, the Union has ample reserves. On this basis no power station could ever be established at the Aughrabies Falls on the Orange River because once the water has reached the bottom of the Falls its further use is ruled out, except on an insignificant scale, since there is no arable land from the Falls to the sea. The Orange River flows in a deep valley, in many places over 1,000 ft., with singularly little arable soil along its banks. The prospects of using much of its water within its own valley are meagre indeed and an ambitious plan is now being intensively investigated to divert a portion of the flow of the river into the adjoining Great Fish River valley. As the watershed separating the two valleys rises to over 1,000 ft. the only way of doing this is by means of a tunnel, which, if constructed, will measure 50 miles in length and will easily be the world's longest. Should this scheme be carried out it opens up magnificent prospects of making use of the Orange River flow before it reaches the Falls but it naturally reduces still further any chances of successfully expoiting the power possibilities which exist there. In many other areas too the urgent need for water would entirely preclude its use in such a manner that any of it is wasted, as it would be if it were used for power generation. The multiple-purpose storage dam seems to offer some scope, but even the most favourable possibilities do not appear so attractive when examined in detail. This is very largely due to the

(Continued on page 62)

Development Problems

In this article A. R. Cooper, Divisional Controller (Merseyside and North Wales Division) of the B.E.A., discusses some of the preliminaries which are incidental to the development of hydro-electric power in Great Britain.

THE Engineering Student who reads this article, should begin by forgetting for the moment all he ever learned about the design of dams, the computation of average rainfalls, geophysical surveys, the flow of water in conduits and all the other fascinating engineering subjects which have to be studied when designing a hydro-electric scheme.

There are other problems associated with hydro-electric developments which can sometimes be more difficult to solve, because they are concerned more with points of view than with matters of fact and can produce clashes of public opinion ranging from arguments in saloon bars to denunciations from the pulpit and debates in the Houses of Parliament. It is the purpose of this article to describe some of these problems and to show the budding engineer who "hates to see water running to waste" just what he is likely to be up against if he endeavours to "harness the forces of nature for the benefit of mankind."

The following notes which are not by any means exhaustive, indicate some of the interested parties whose views have to be considered and with whom some form of agreement has in general to be negotiated when a hydro-electric project is being considered in Great Britain.

Agricultural interests will complain that the flooding of land will reduce food production, and that the monopolising of the sheltered lowland areas in the valleys for water storage will upset the balance of the hillside farming economy. Farmsteads and possibly whole villages may be submerged, and families which have lived for many generations in the same locality will have to be uprooted and transplanted elsewhere. It will be stated that diversion of streams will dry up the land, stop any form of agriculture, and deprive farms of the water they need for cattle and domestic purposes, and that the construction of leets or channels along the hillsides will prevent the movement of sheep and will alter farm boundaries. Answers to these points will usually indicate that the area of land actually to be submerged is relatively very small, a typical figure being well below one per cent. of the total catchment area, whilst the land to be flooded is usually either boggy or only suitable for rough grazing. The submersion of some homesteads is normally unavoidable and is probably the unhappiest aspect of any hydro-electric scheme. No one would suggest that a cash value can be given to the sentimental ties and traditions which are close to the hearts of so many hill farming people; one can only endeavour to obtain the sympathetic collaboration of the people concerned, by making them familiar with the wider issues involved, and by taking an active and personal interest in their changed and what will probably be their improved habitation.

It will be necessary to explain that the introduction of hydro schemes will not cause the land to dry up, as the water used will only be the run off water which would otherwise have found its way to the sea. Where stream flows are diverted the farms affected will be provided with a piped supply of water which will in general be much more reliable than streams which were affected by droughts and floods. It can be pointed out that some measure of control of the headwaters of a stream or river will do much to prevent or minimise the floods which have frequently removed valuable top soil from so many farms. Leets or channels round hillsides need not affect farm boundaries. They will be spanned by bridges at appropriate places to facilitate the movement of sheep, and will be protected by fencing where sheep would otherwise have access. Local councils and planning authorities will need to be convinced that the proposed schemes do not interfere with their own plans for the development of the area especially in such matters as water supplies, roadways, housing and industrial developments and general amenities.

In many cases it will be possible to show that in collaboration with the water supply authorities reservoirs can be designed to serve the needs of both parties. These arrangements can provide added security to the town's water supply, for in times of severe droughts, generation can usually be restricted to enable the stored water to be used for the more urgent domestic supply.

Road diversions will have to be agreed, both for route and design, with the authorities concerned and some indication will have to be given of the methods which will be adopted for disposing of the spoil produced by tunnel excavation.

Fishing interests will have to be protected and agreement will have to be reached with the appropriate fishing boards, as to the amount of compensation water which will be necessary to maintain fish life in the streams at its original level. Where the construction of dams would prevent fish, such as salmon, returning to their spawning grounds, fish ladders provided with adequate water flows will have to be provided. In certain cases it may be necessary for the proper conservation of fish life to construct fish hatcheries.

Serious consideration will have to be given to afforestation projects which are frequently carried out on a large scale on mountain slopes, as the planting of trees on what would otherwise be bare land can reduce the total run off by as much as 10 per cent., an amount which can have an appreciable bearing on the economics of a scheme. In cases of this nature, as indeed with most of the problems which have to be faced, some compromise solution has usually to be adopted. The approach by all parties

Fig. 1. Maentwrog Scheme: hydro-electric power station with Trawsfyndd reservoir in background

Fig. 2. Dam and fish pass on the Galloway scheme

should, in principle, be that the natural resources are being utilised in the best interests of the country as a whole.

River boards will have to be consulted if any schemes envisage the diversion of streams from one watershed to another. Although the amount of such diversions may be small, it may be argued that they can have critical effects on silting conditions and particularly on minimum dry weather flows.

All the foregoing are matters of fact, which can usually be argued to a reasonable conclusion between sensible, well-informed people, and cases may arise in which the amounts of compensation water to be supplied or the additional works to be constructed may be such that a hydro-electric project becomes uneconomic and has to be abandoned.

There is another form of objection, however, usually associated with the preservation of amenities which deals in matters of opinion rather than matters of fact, and it is in this quarter that the battle rages fiercest. "Vandalism" is one of the politest terms used by the opposition and the whole subject provides a happy hunting ground for elderly gentlemen who like to see their names before the public, rambling and climbing associations who fear that their favourite haunts will be despoiled, free-lance journalists who scent sensational copy, and well-intentioned but woolly minded aesthetes who want electricity but don't want power stations or transmission lines. It is of no use to quote the amount of coal which will be saved by the hydro scheme, or to point out that hydro plant has no chimneys, cooling towers or railway sidings and that it does not produce thousands of tons of ashes which would have to be distributed over the countryside or dumped out at sea. Your arguments will be ignored or your figures distorted and anything in the nature of reasonable discussion will probably be impossible. The practical steps which can be taken are to meet the comparatively stable organisations such as the local authorities, the planning authorities, the advisory Boards for Industry, and any other official organisations which are providing a public service and to discuss with them the pros and cons of the individual projects. The Members of Parliament for territories included in the catchment areas will probably also have to be met, especially as their support may be needed if a special bill has to be presented in Parliament.

If and when Parliamentary powers are being sought, the legal and parliamentary procedure might easily last a year or more, and if powers are finally granted in some form of Enabling Act, it will still be necessary to hold a public enquiry wherever any scheme is being opposed. Such enquiries would be arranged by the appropriate Ministry, and this procedure would take at least six months and probably much more to produce a decision.

It will be seen from the foregoing, that a hydro-electric project can carry with it many more problems than those associated with the actual design and construction of the works. The engineer in charge will have many calls on his time, tact and patience which have nothing to do with the subjects he studied at college, and he will discover that with hydro-electric engineering, as with most other professions, it will be necessary for him, in addition to being technically proficient, to be also something of a philosopher.

From our Parliamentary Correspondent

Recently Mr. Sorensen asked the Secretary of State for the Colonies, in view of the large production of bauxite in British Guiana and the abundance of water power in that Colony, what financial and other steps had been taken to secure a hydro-electricity survey, with a view to ensuring the supply of electricity to British Guiana and enabling that Colony to manufacture aluminium.

Mr. Dugdale, Minister of State for Colonial Affairs, replied that preliminary investigations, such as measuring the flow of water at individual falls and aerial photography, were now being carried out. Some time must elapse before it would be possible to determine the prospects of developing hydro-electric power in British Guiana at the cost and on the scale required for the manufacture of aluminium in competition with existing manufacturers.

Mr. Dodds-Parker asked whether a date and charges for the purchase of electricity from the Owen Falls Power Station had yet been scheduled.

Mr. Dugdale said it was hoped that the dam would be completed and the first four generator sets installed by 1953.

Mr. Dodds-Parker asked what action was being taken to attract industry to utilise the electricity supply to be obtained from the Owen Falls Dam.

Mr. Dugdale said that discussions had been held, and were continuing, between representatives of the Uganda Government and firms likely to be interested in establishing themselves in Uganda.

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high cost of civil engineering works which would be required to enable the stored water to be effectively used, even if such use could be arranged in a manner involving no clash of interests with other users.

There are two other factors, namely, silt and evaporation, which have far-reaching influences on all problems of water conservation, including that of stabilising river flows for power purposes, which cannot be dealt with in a brief review such as this. These factors which have a small significance in more humid countries are so important in South Africa, where evaporation from a free water surface may be as much as 90 in. per annum, and where mean silt contents of 3 per cent. in the inflow are quite common, that they are in many cases the final criterion as to the feasibility of a project.

We cannot but conclude that the generation of hydro-electric power on any substantial scale in South Africa is practically ruled out. Only in a very few favourable localities is such generation likely to be either physically or economically practicable. This is due mainly to the following considerations:—

1. The flow of South African rivers is too erratic.
2. Stabilisation of the flow by means of storage dams will be very costly.
3. Water is so scarce that what is available must be reserved for domestic use and for agriculture and industry.
4. Large reserves of coal enable power to be cheaply produced in thermal stations.

Pelton or Francis Turbines for High Heads?

By RAYMOND C. COLLET of Charmilles Engineering Works Limited of Geneva. This article discusses the relative merits of Pelton and Francis turbines for heads ranging between 300 and 400 metres and advocates the application of Francis turbines in preference to Pelton units which have hitherto been used in most cases for such high heads.

L'emploi croissant de turbines Francis, au lieu de Pelton, dans les centrales de haute chute est l'un des faits les plus remarquables dans l'évolution de la construction hydro-électrique. L'auteur montre que cette tendance est économiquement saine puisque le rendement des turbines Francis est supérieur, et le coût de leur entretien inférieur à ceux des turbines Pelton. En outre la durée de fonctionnement entre deux visites générales est plus grande du fait que l'usure affecte moins le rendement d'une Francis que d'une Pelton et que les travaux de soudure y sont plus faciles à faire.

Uno de los desarrollos más salientes de la ingeniería hidroeléctrica es la proporción constantemente creciente en que se adoptan turbinas de tipo Francis para saltos altos con preferencia a las turbinas Pelton. Se lleva demostrado que este desarrollo es acertado desde el punto de vista económico, debido a que está basado sobre la mayor eficiencia que es posible obtener y los gastos más bajos de mantenimiento. Además, la turbina Francis funcionará por espacio de períodos de tiempo más largos entre repasados, debido a que cualquier desgaste es de un efecto menos importante en la eficiencia de lo que sería tratándose de una turbina Pelton y las reparaciones por soldadura pueden ser llevadas a cabo de manera más fácil.

THE progress achieved in hydraulics, in parallel with similar improvements made in other branches of engineering, has extended more and more the field of application of the various types of turbines.

Kaplan turbines, which were at first only applied to heads of less than 10 metres, in course of time topped the 20 metre and the 40 metre limits and the present record is held by a Charmilles machine which operates on a head of 56 metres. Similar progress has been made with Pelton turbines although the possibilities here are restricted by the fact that operating heads of 1,500 to 2,000 metres are extremely rare. Francis turbines have naturally followed the higher-head trend and if for low head installations they are being superseded by Kaplans, they are on the other hand encroaching more and more on the field which was thought, some thirty years ago, to be unquestionably reserved to Pelton units. This implies, however, that for very high heads (400 to 500 m.) the turbine discharge is sufficient to lead to runner dimensions that are large enough for accurate machining.

The race of Francis runners towards higher operating heads is yet in course of development and if at times the preference is still given to Pelton turbines, the reason is not that the Francis is inadequate but rather that some operators lack confidence and not all manufacturers have the necessary experience.

The progress made in hydraulics, particularly in regard to Francis turbines, has also been assisted to a considerable extent by improved metallurgical practice which has resulted in the production of special-quality steels. The use of high-tensile stainless steels has allowed high-head Francis turbines to be constructed which will operate satisfactorily even when fed with moderately sand-laden water.

This progress has presented new problems not only to the turbine manufacturers but also to the manufacturers of the generators who now, however, have no hesitation in producing machines capable of dealing with 80,000 h.p. generators at 750 r.p.m.

In 1930 a record was established when the Charmilles works built the turbines for the Piottino Power Station, Switzerland, the main characteristics of which are given in Table I, together with those of a number of other Francis turbines which have been built subsequently. (See Fig. 1).

TABLE I
HIGH HEAD FRANCIS TURBINES BUILT SINCE 1930

Name of Power Station	Number of units	Operating head metres	Output per unit h.p.	Specific speed (metric)	Speed r.p.m.
Piottino	2	323	32,000	93	750
Lamadjan	3	208	9,000	72·1	600
Casteldelfino ..	2	313	20,700	82·2	750
Sampeyre	2	332	24,500	83	750
Provvidenza ..	2	290	70,500	111	500
Lardit	2	336·5	32,040	93·2	750
Lages	4	335	54,100	97·5	600
Rouze	1	239	10,000	79·5	750
Peyrat-le-Château	3	250	26,000	97·3	600
Marcillac	2	232	23,000	100·5	600
Afourer	2	228·5	65,000	122·8	428·6

Francis and Peltons compared

A Pelton wheel must always, of course, be set at a higher level than the highest tail-race level and therefore shows a loss of head when compared with the Francis turbine which, owing to the draft-tube,

makes use of the total available head. Attempts at partial recovery of the head lost below the Pelton wheel have been made by resorting to hydro-pneumatisation, but this method has proved both complicated and unsatisfactory. Moreover, even with a hydro-pneumatised unit, in which the partial vacuum causes the free level of the water to rise in the turbine housing, a part of the head cannot be recovered as it is obviously essential that a sufficient distance should be maintained between this free level and the runner.

The Francis turbine therefore shows a distinct advantage, particularly in installations in which the variations of the tail race level are important. In the case, for example, of a plant operating with a head of 1,000 ft. and having a tail-race level varying by 10 ft., the Francis turbine, which can operate perfectly well with a "back pressure," can make full use of the total head even if the conditions to be observed to avoid cavitation require that the runner should be placed at a level very near, or below, the lowest tail-race level. In the case of the Pelton, however, the runner will necessarily have to be placed at least 6 ft. above the highest tail-race level, and hence in respect of the operating head sustains permanent loss of between 0·6 and 1·6 per cent. Nowadays, when the least shortage of turbine efficiency is heavily penalised, this loss should, in our opinion, be avoided by giving preference whenever possible to a Francis unit.

A further advantage of the Francis lies in the fact that it accommodates variations of operating head far better than a Pelton. Both theory and practice show that a Francis turbine with a specific speed of about 100 r.p.m. (metric) operating under a head of 300 m., can accommodate variations of the peripheral velocity u_1 amounting to $\pm$ 20 per cent. of the normal value. In consequence, the ratio between the maximum and minimum operating heads can reach even 2 without major inconvenience.

A Pelton turbine is much less pliant in this respect. If abnormal wear of the buckets is to be avoided the velocity ratio u_1 should not vary more than $\pm$ 10 per cent. of normal, with resulting reduction of the ratio between maximum and minimum head to approximately 1.4. Of course, head variations of this importance are not frequent for plants operating at heads of 300 to 500 metres; but the fact remains that Francis turbines adjust themselves better to varying water levels in a storage reservoir and will therefore use this storage to better advantage and with an improved mean efficiency.

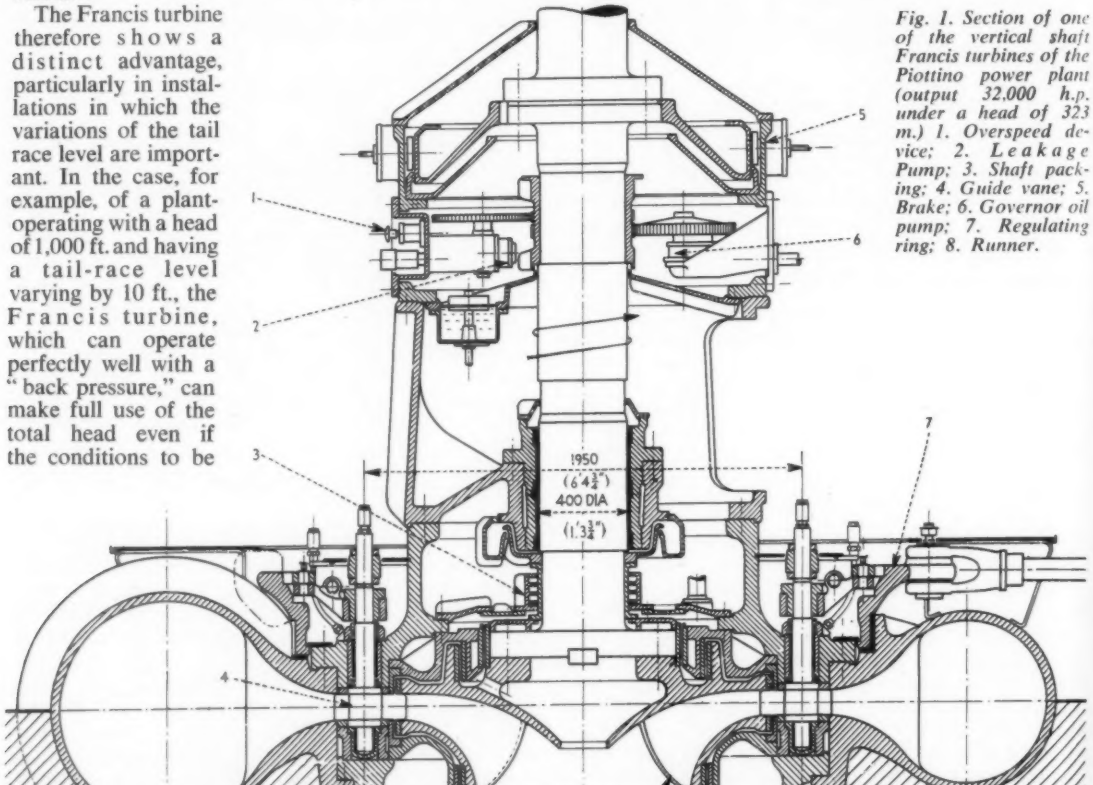


Fig. 1. Section of one of the vertical shaft Francis turbines of the Piottino power plant (output 32,000 h.p. under a head of 323 m.) 1. Overspeed device; 2. Leakage Pump; 3. Shaft packing; 4. Guide vane; 5. Brake; 6. Governor oil pump; 7. Regulating ring; 8. Runner.

Efficiencies

Without going too far into the theory of water

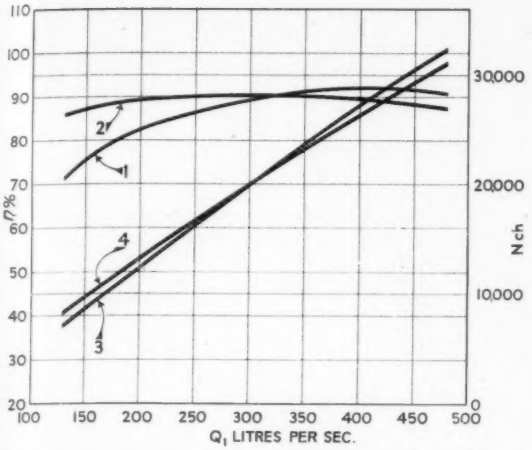


Fig. 2. Piottino Power Station. Comparison between the efficiencies of Francis turbines and the corresponding vertical shaft Pelton turbines.

	Head	*Output*	*Speed*
	m.	*h.p.*	*r.p.m.*
Francis	*313*	*29,800*	*750*
Pelton	*310*	*28,500*	*300*

Curve 1: Francis efficiencies plotted against specific discharge $Q_1 = \dfrac{Q}{\sqrt{H}}$;

Curve 2: Pelton efficiencies plotted against specific discharge Q_1;
Curve 3: Francis output plotted against specific discharge Q_1;
Curve 4: Pelton output plotted against specific discharge Q_1.

turbines, a brief survey of the conditions of operation of a Francis and of a Pelton turbine will be sufficient to draw a useful comparison between the efficiency curves of these two types of machines.

(*a*) The Pelton being of the "impulse" type (or, more accurately, of the free-deviation type) whereas the Francis is a "reaction" turbine, the amount of deviation which is enforced on the stream of water by the runner buckets is much less important in the Francis machine.

(*b*) The fact that the stream of water, at the inlet to a Pelton bucket, affects the shape of a free jet with a high absolute velocity (equal practically to the velocity of a falling body, *i.e.* $\sqrt{2gH}$), combined with the manner in which this jet impinges in the bucket and flows through it, leads to flow conditions that are considerably more difficult than in a Francis turbine. This feature will be discussed in more detail under the heading "Wear."

(*c*) The jet of a Pelton turbine strikes the runner at variable points and under variable angles so that an impulse runner is necessarily a compromise even for the conditions corresponding to the design head and output. On the other hand, theoretical conditions are not modified in a Pelton wheel by variations of the output. In the case of Francis turbines, on the contrary, the velocity diagrams change with the output and therefore, when the output varies from the design output, there appears a shock component in the velocity at the inlet of the runner and a tangential velocity component at the outlet.

For the foregoing reasons the ceiling of the efficiency curve of a Pelton wheel will remain slightly lower than that of a Francis turbine but the efficiency curve will be less affected by variations of the load. Fig. 2 shows, for example, the efficiencies measured during the acceptance tests of one of the Piottino Francis turbines and the corresponding efficiencies of a modern Pelton turbine designed for the same conditions of head and output. The curves confirm theoretical considerations and it can be asserted that for the large outputs considered in this study, the Francis turbine is superior to the Pelton between full load and half load (Fig. 2). This balance in favour of the Francis turbine is further increased by the gain in the operating head, which amounts, in fact, to an augmentation of the overall efficiency of the plant.

Because of the wider latitude within which the velocity coefficient of a reaction runner can vary, as explained above, the Francis turbine has a decided advantage as regards efficiency if the operating head varies appreciably. One grasps this immediately on comparing the efficiencies of both types of turbines plotted in a three-dimensional or contour-type diagram. The foregoing considerations apply to and are valid for turbines that are new or in a perfect state of repair, and it is therefore merely logical to examine also the extent to which these efficiencies will be maintained during operation. This important question, which is linked up with the effects of wear, is examined in another paragraph.

Speed

Here again theoretical considerations, supported by the knowledge of the limits of certain velocity coefficients acquired by experience, must supply the basis of discussion. Let it first be recalled that the specific speed of a turbine — whatever the type — expressed as a function of the available data, *i.e.* output, head and speed, is given by the equation:—

$$n_s = \frac{n}{H}\sqrt{\frac{N}{\sqrt{H}}} \qquad (1)$$

This specific speed can also be expressed as a function of the dimensions and of the velocity coefficients for the two types of turbines as follows:—
Francis turbines

$$n_s = 576\ u_1\ \frac{D_2}{D_1}\sqrt{c_{m2}\ .\ \eta} \qquad (2)$$

Pelton turbines

$$n_s = 567\ u_1\ \frac{d}{D_1}\sqrt{\eta} \qquad (3)$$

In equations (1) to (3)

n_s = the specific speed (metric),
n = the speed in r.p.m.,
H = the head in metres,
N = the output in horsepower (metric),
u_1 = the peripheral velocity coefficient at the runner inlet = $\dfrac{U_1}{\sqrt{2gH}}$
cm_2 = the meridional velocity coefficient at the runner outlet,
D_1 = the inlet diameter of the runner (diameter tangent to the centreline of the jet in the case of a Pelton turbine), in metres,
D_2 = the outlet diameter of the runner (Francis) in metres,
d = the jet diameter (Pelton) in metres,
η = the efficiency.

On substituting the symbols by the corresponding

values of the efficiencies and of the velocity coefficients* for the head under consideration, there will result the following equations expressing the relations between fundamental turbine diameters which, in turn, determine the practical constructional limits :—

Francis turbines $\quad n_s = K_1 \cdot \dfrac{D_2}{D_1}$

Pelton turbines $\quad n_s = K_2 \cdot \dfrac{d}{D_1}$

On examining the hydraulic profiles of these two types of turbines for various values of the n_s one sees immediately that there are :—

(*a*) A lower limit† for the specific speed of Francis turbines. It is clear that the ratio $\dfrac{D_2}{D_1}$ cannot be reduced below certain limits without leading to inlet channels which are too narrow, too long, difficult to manufacture and, moreover, theoretically unfavourable. In practice the n_s (metric) should, generally speaking, not be less than 60 to 70.

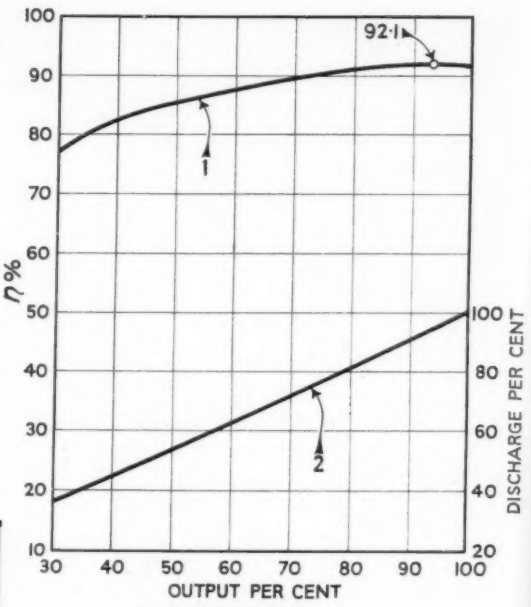
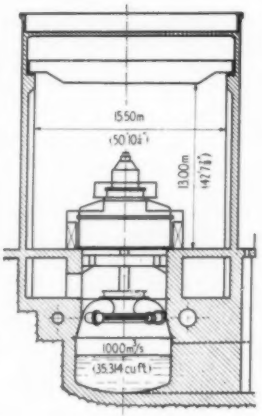
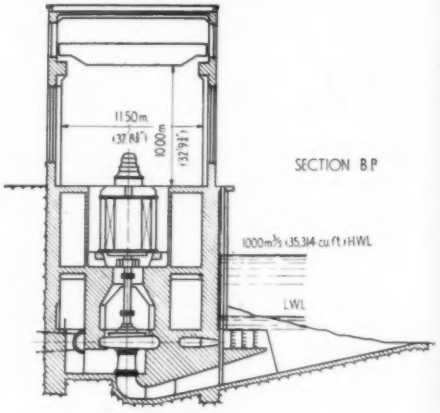


Fig. 3 (top right). Lages Power Station. Vertical shaft Francis turbine. Output 54,100 h.p.; Head 335 m.; Speed 600 r.p.m. Curve 1: efficiencies plotted against output. Curve 2: measured discharge plotted against output.



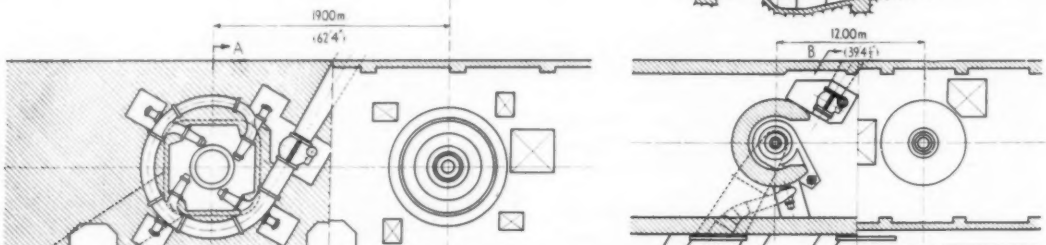
SECTION A.A



SECTION B.P

Fig 4. Comparison of power house dimensions required for Pelton and Francis turbines

		Francis	*Pelton*
Head	...	*445*	*435 m*
Output	...	*80,000*	*80,000 h.p.*
Speed	...	*750*	*300 r.p.m.*

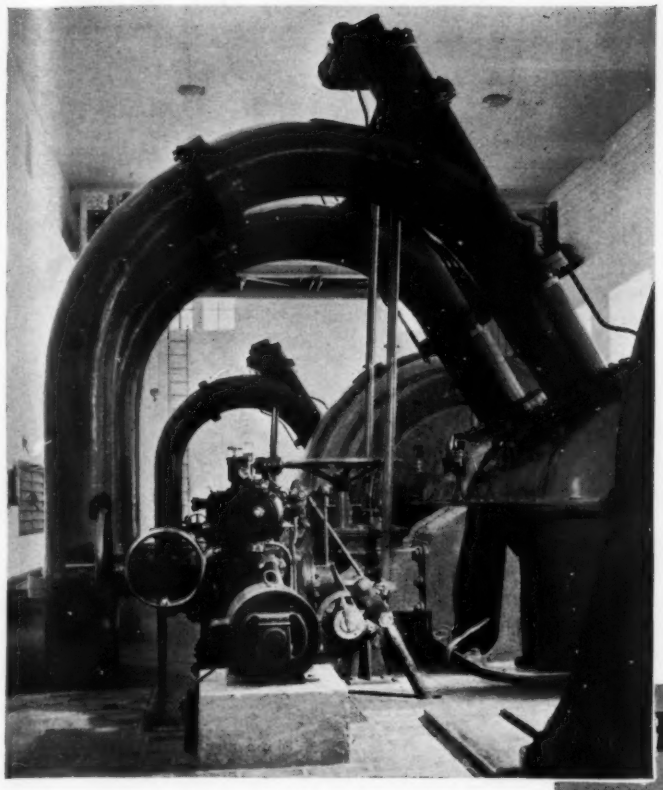


(*b*) An upper limit† for the specific speed of a Pelton turbine. As the diameter d determines the dimensions of the buckets, the ratio $\dfrac{d}{D_1}$ cannot be increased beyond limits that are compatible with a sufficient number of buckets, a robust connection between buckets and hub, and a proper evacuation of the water towards the centre of the runner. In practice, for a head of about 300 m., the n_s should not exceed 30 per jet.

For given operating conditions, the speed of a Pelton turbine could reach the lowest speed which can be considered for a Francis only by providing it with at least four jets. Where the large outputs under consideration are concerned, besides the inconveniences

*These values, it must be remembered, are given by theory and experience, and correspond to the best conditions of operations, *i.e.* to the highest efficiency.

†There is, of course, both an upper and lower limit for each type of turbine. However, only those mentioned above are useful in the present comparison.



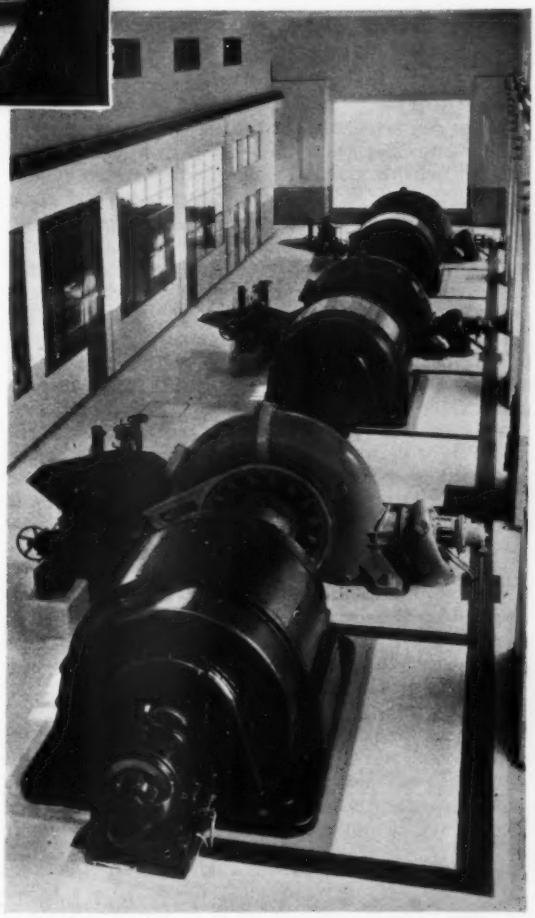
The maximum tail-race level shown is the highest which can occur during operation and of course the Pelton wheel must necessarily be placed above this level. The volume of the foundation concrete appears to be roughly the same in both cases but the width of the power station and the distance between the centrelines of two consecutive machines is definitely in favour of the Francis machines.

Wear

The foregoing is sufficient to indicate that a turbine manufacturer with the necessary experience can design Francis turbines for operating heads of 300 metres and more, and which not only have excellent efficiencies but can also

Fig. 5. Gampel Station: 4 jet Pelton turbine. Output 6250 h.p.; head 205 m.; speed 500 r.p.m. Note the dimensions of the supply pipes

Fig. 6. Martigny-Bourg Station: Three twin Francis turbines with relief valves. Compact units, small overall dimensions

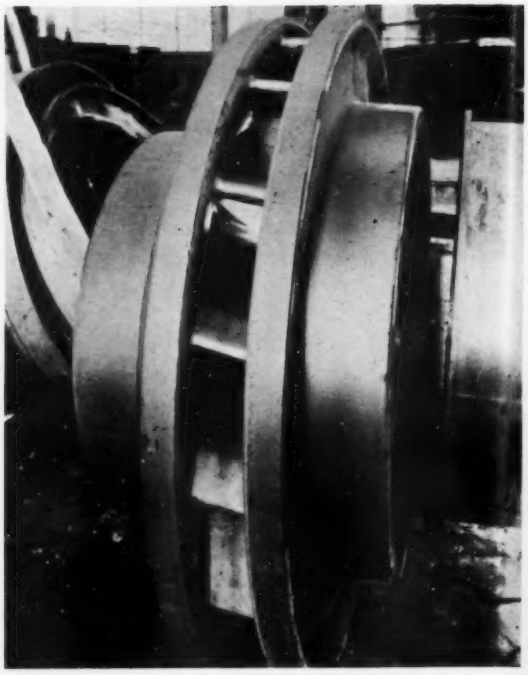


inherent to a four-jet turbine, it is common knowledge that high specific speeds are inappropriate for multiple-jet turbines, with the consequence that Pelton turbines will always run at an appreciably lower speed than a Francis designed for the same conditions.

Dimensions

With the higher speeds obtainable with Francis turbines it follows that their overall dimensions will be appreciably smaller than those of the equivalent Pelton machine. Moreover, the water admission to the turbine (spiral casing and guide apparatus) surrounds the Francis runner much more closely than the supply pipes of the Pelton which are necessarily designed with gently radiused sweeps to obtain the regular, easy curves to reduce as far as possible the rotational component of the velocity, which is very detrimental to the quality of the jet. For similar reasons the water velocity in the lead-in pipe of a Pelton turbine is generally kept much smaller than in the spiral casing of a Francis turbine, and this naturally leads to larger diameters and consequently to a further increase of the dimensions of a Pelton turbine. The ground-views and sectional elevations shown in Fig. 4 give a comparison of the space taken up by a Pelton turbine and by a Francis turbine designed for the following similar operating conditions :—

	Francis Turbine	Pelton Turbine	
Head	445	435	m.
Output	80,000	80,000	h.p.
Speed	750	300	r.p.m.



Figs. 7 and 8. Piottino Power Station. Bronze runner of one of the Piottino turbines after 100,000 hours of operation; total output more than 1100 × 10^6 kWh.

run at favourably high speeds. However, it is of primary importance that the efficiency of such a turbine should remain high even after many years and without frequent stoppages and high maintenance costs. This problem concerns water-turbine practice as a whole but is of particular importance in the case of high-head machines, especially if the water contains abrasive sand. No mention will be made here of the wear due to cavitation because an experienced manufacturer can always avoid cavitation by adopting an appropriate design and setting.

Various publications* show how sensitive Pelton turbines are to the wear, however small, of the needles, nozzles and of bucket splitters. It is easy to understand that with the high water velocities which occur in a Pelton bucket the least roughness of the nozzle and needle surfaces will cause a distortion of the jet which will cause it to spray, lose its compactness and to impinge on the buckets in conditions that are very detrimental to the efficiency of the machine.

In a recent article, Mr. Aemmer shows that the efficiency of a Pelton turbine can decrease considerably, and can be reduced as much as 9 per cent. even when the wear of the needle and nozzle does not exceed more than 0·5 to 1 mm.

As regards the runners, the Francis is favoured in that the water velocities are considerably lower and the bucket curvatures much less sharp. The weakest point of Pelton buckets, with respect to wear and its influence on efficiency, are the lips and the tips of the splitters. The jet impinges on these parts with an angle which varies considerably and with a relative velocity of about 0·5 $\sqrt{2gH}$; the jet at this point must be split and divided not only between the two bowls of the same bucket but also between two consecutive buckets with the least amount of distortion and spraying. This implies the use of sharp, slender splitters which, unfortunately, are relatively frail and susceptible to wear; they thus require constant care and repairs, or otherwise the turbine efficiency will fall away very rapidly.

Conditions are much more favourable in a Francis runner where the stream of water is perfectly guided and enters the blading at a much lower velocity; the runner blades are streamlined and have thick rounded inlet edges which permit considerable variations of the angle of approach of the stream of water without detriment to the efficiency.

Francis turbines are, however, sensitive to the abrasive effect of sand passing over the cheeks of the distributor, between these cheeks and the guide vanes, and through the runner clearances; this wear can, however, be mastered satisfactorily by judicious design of the runner clearances and by the use of appropriate materials. This has been confirmed by several high-head machines, particularly by the Piottino turbines which have been carefully and regularly inspected. These turbines operate under a head of 323 m. and the water contains granite sand. They were designed for operation at two speeds, 630 and 750 r.p.m., and notwithstanding these severe conditions both the original runners can be credited, at the time of writing, with over 100,000 effective hours of operation (Figs. 7 and 8). The only maintenance work carried out on the runners has been to repair or replace the wearing bands after every 15,000 to 18,000

*See, amongst others, Mr. Aemmer's article "Ueber den Einfluss von Nadeln und Düsen auf den Wirkungsgrad von Pelton-Turbinen," Bulletin A.S.E., 1943, No. 13.

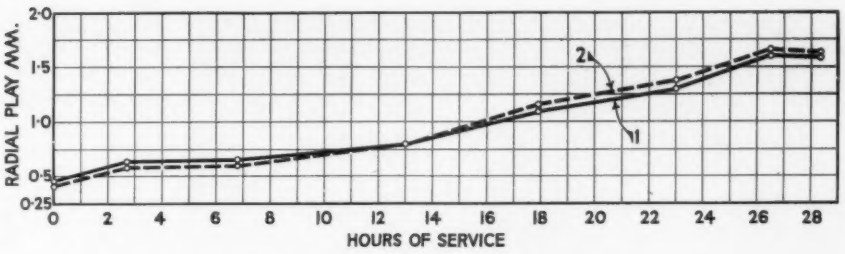


Fig 9. Piottino Power Station: Wear of the runner bands plotted against hours of operation. Curve 1: upper clearance. Curve 2: lower clearance

hours of operation. Fig. 9 shows how the radial clearance between the runner bands and the stationary rings increases with the number of hours of operation. In one case the radial clearance reached 1·7 mm. after 29,000 hours and tests made before the clearance surfaces were renewed showed that the turbine efficiencies were practically unaffected by this amount of wear. At the time that the Piottino turbines were built the technique of stainless steel was not as advanced as it is to-day and therefore the original runners, which are still in operation at the time of writing, were made of bronze. It has therefore not been possible to repair them by welding and the fact that they are still in perfect order after more than 100,000 hours of effective operation is particularly conclusive evidence in favour of high-head Francis turbines.

Stainless steel runners are now used in preference to bronze and this metal has the added advantage of being repairable by welding (Fig. 10). The life of a stainless-steel runner should therefore be much longer than that of a bronze runner.

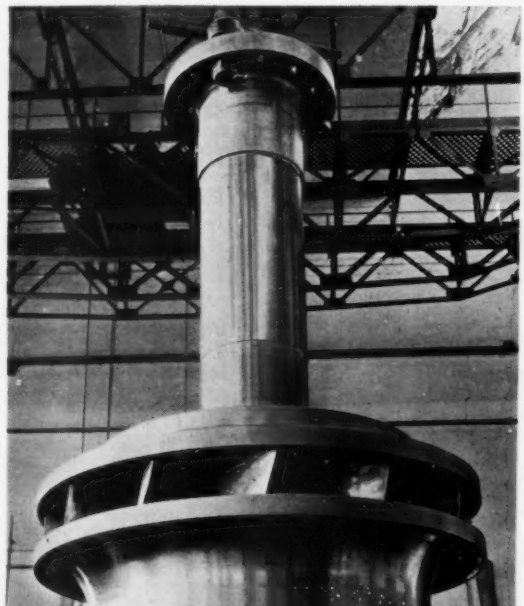


Fig. 10. Lages Power Station. Stainless steel runner of one of the four Francis turbines. Output 54,100 h.p.; head 335 m.; speed 600 r.p.m.

A plant which has to deal with water containing abrasive materials should always be preceded by a sand-arrester, whether it be equipped with Francis or Pelton runners. In the case of Piottino, the water used comes directly from glaciers and during the summer season it contains a considerable amount of granitic sand. The sand-arrester prevents all grains of more than 0·5 mm. diameter from entering the system but the grains smaller than 0·4 mm. inevitably pass through the turbines. The concentration of sand suspended in the water before it reaches the sand-arrester varies between 2,400 and 5,600 milligrammes per litre of water. This concentration is reduced by the sand-arrester to approximately 200 to 600 milligrammes per litre, but even so it must be remembered that there still is between 96 to 288 kg. of sand going through each turbine runner every minute.

Maintenance

The overhauling of a Francis turbine generally entails the adjustment of the runner clearances by replacing the stationary rings and touching up the runner bands, or *vice versa*, and eventually the refacing of the distributor linings. It is very seldom necessary to repair the runner blading by welding and even then no annealing is required as local stresses have not the same importance as in Pelton runners.

The welding of the guide vanes requires no exceptional skill and can be done on site in the power-house repair shop so that, really, the only delicate task required for the maintenance of a Francis turbine is the upkeep of the runner bands and stationary rings; no building up and reshaping of the hydraulic profile is required.

For a Pelton turbine, on the contrary, besides replacing the needle tip and the throat ring of the injector, each bucket must be repaired by welding over the whole or part of its surface and the splitter and cut-out must be carefully built up and reshaped. The buckets must then be ground down to their original shape; this work can only be done by hand and requires careful checking by means of the original templates. After grinding it is advisable to anneal the runner so as to relieve local stresses caused by the welding and to make a careful inspection for shrinkage cracks, etc. This work is of extreme delicacy and requires a great deal of skill; moreover it must be frequently repeated if the efficiency of the turbine is to be maintained within a reasonable measure of the initial figure. The relative simplicity of access and dismantling which is generally a feature of Pelton turbines is therefore more than counterbalanced by

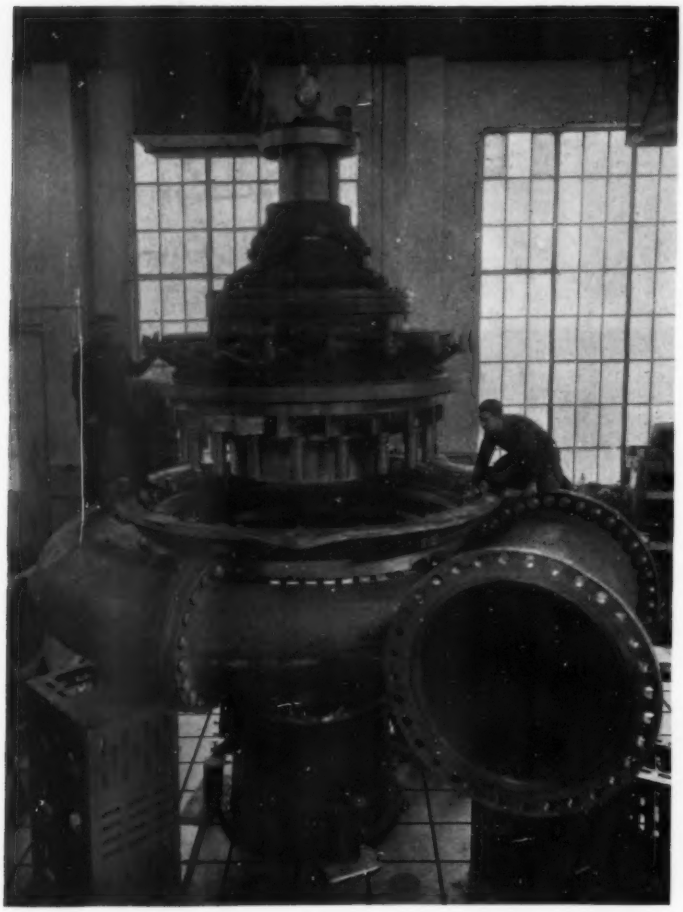


Fig. 11. Lages Power Station. 54,000 h.p. turbine at 335 m. head. Erection of central portion of the turbine comprising: the runner, the cover plate, the guide vanes, the lower section of the shaft and the guide bearing

the frequency with which overhauls are necessary.

On the contrary the efficiency of a Francis turbine is not nearly so sensitive to wear; moreover it is fairly easy to take steps to minimise the time required for replacing those parts which are subject to wear (Fig. 11). In support of this assertion mention may be made of the Lages turbines (54,100 h.p. each under a head of 335 m.) and of the time required to keep these machines in perfect condition over several years. During the nine years from January 1940 to March 1949, one of these turbines required 2,128 hours for inspection and repairs, *i.e.* an average of 230 hours per year, which is relatively high compared with the figures given further on for the other turbines of this plant. This high figure is due to the fact that this machine, which was the first of this type to be installed in the Lages Station, served as an experimental unit and was formerly inspected and dismantled at comparatively frequent intervals in order to supply detailed information as to wear resistance, with a view to ascertaining which spare parts it might be convenient to provide sooner or later. Moreover, the operating staff had to get acquainted with the new equipment, with the result that only a small fraction of the total outage time was actually spent on repair work. Even so, during these nine years the unit was operated for 38,399 hours so that the 2,128 hours required for inspections and repairs amounted to 2·7 per cent. of the total.

The second turbine, which was similar in design, required 385 hours for inspection and repairs between June 1942 and March 1949. During this period it was operated for 29,688 hours; the average time spent on maintenance has therefore only amounted to 57 hours per annum, the work being of course carried out when the turbine was not required for load.

The third similar turbine required only 108 working hours for inspections and maintenance between February 1947 and March 1949, during which period it was operated for 9,814 hours. The average in this case is therefore about 50 hours per annum.

These figures have been reported by the plant operating staff and are therefore absolutely dependable. In our opinion they are an excellent proof of the reliability of high-head Francis turbines if correctly designed.

Regulation

When a Francis turbine is equipped with an entirely reliable system of relief valves, the closing time of such a turbine can be as short as that of the deflector of a Pelton turbine, *i.e.* less than 2 to 3 seconds in most cases.

The flywheel effect required for a unit is expressed by:—

$$PD^2 = \left(\frac{520}{n}\right)^2 . N . t . F_v . C_m . \frac{1}{\lambda}$$

where :

PD^2 = the flywheel effect of the unit rotor, in kgm^2,
n = the speed of the turbine in r.p.m.
N = the maximum turbine output, in metric horsepower,
t = the closing time of the turbine, in seconds,
F_v = a coefficient expressing the kinetic energy accruing from the pressure surge due to the closure,
C_m = a coefficient characterising the type of turbine, runner, mode of regulation, etc.,
λ = $(1 + \Delta n)^2 - 1$ defining the maximum speed rise Δn.

We have seen that for the same output N, the closing time t was practically the same for the two types of turbines. Theoretical considerations, too long to expound in this article, show that F_v is for all practical purposes equal to 1 in both cases. There remains therefore C_m and λ which can take different values. For a Pelton of our design, measurements have shown that C_m is equal to 0·65 whereas for a Francis this coefficient equals about 1.

It follows that the ratio of the λ is

$$\frac{\lambda \text{ Francis}}{\lambda \text{ Pelton}} = \frac{1}{0{\cdot}65} = 1{\cdot}54.$$

Calculating Δn for a normal value of λ the following comparable figures are obtained for maximum speed rises :—

Δn Francis = 27 per cent.
Δn Pelton = 18 per cent.

This shows that, all other factors remaining equal, when full load is thrown off, the momentary speed rise will be about 50 per cent. higher for a Francis unit than for a Pelton unit. The following figures show however that this difference diminishes very rapidly for partial load rejections:

	Δn Francis	Δn Pelton
Load thrown off $= N$	27	18 per cent.
Load thrown off $= \frac{N}{2}$	9.5	7 per cent.
Load thrown off $= \frac{N}{4}$	4.5	4 per cent.

The advantage of the Pelton is therefore important only when full load is thrown off, but in this case the speed rise is of no particular significance because it can only occur when the unit is disconnected from the network. In our opinion the speed variations corresponding to partial load rejections are of much greater importance and the foregoing figures show that regulation under normal conditions of load variations is practically the same for Francis as it is for Pelton turbines.

The pressure rise in the penstock is not a function of the closing time of the guide vanes, but of the relief valve, which can be adjusted as easily as that of the needle of a Pelton turbine. The penstock will therefore be placed in the same conditions in both cases. If the length of the diversion works is such that a surge tank is required, this surge tank will be necessary whether the turbine is a Francis or a Pelton. These two types of turbines will also be equivalent as regards speed and pressure regulation if, as is exceptionally the case, it is possible to resort to normal regulation by means of the guide vanes or the injector needle only, *i.e.* without having recourse to a relief valve or deflector.

It might be objected that if the unit is to operate as a synchronous condenser the Francis has the disadvantage of requiring the closure of the inlet valve because the guide apparatus in closed position is not absolutely watertight, whereas with a Pelton wheel, if the needle tip and throat ring are in good repair, watertightness is assured. Consequently the switch back to generation after operation as a condenser will require more time for a Francis than for a Pelton turbine. In this case also, special provisions, and particularly self-closing needle valves, can be applied to reduce appreciably this slight disadvantage of the Francis; this question, however, can hardly be considered as a determining factor in the choice between the two types of machine.

Conclusions

The encroachment of the high-head Francis into the field so far reserved for impulse turbines, is due to the progress achieved not only in hydraulics but also in metallurgy, the latter having resulted in the manufacture of high grade alloys. Improved electrical equipment has also played a part. Francis turbines such as have been discussed in this article have long passed the pioneer stage. An experienced designer, making full use of the materials which are now available, is able to supply Francis machines which experience has proved to be entirely reliable.

To sum up, the points in favour of the Francis turbine are, a more complete utilisation of the head and higher operating efficiencies for loads ranging between half and full load.

The gain in the utilisable head is undeniable, and is entirely independent of the load. The question of the efficiencies deserves to be examined, in each particular case, according to the load factor of the machines. With plants having storage reservoirs working according to predetermined programmes it is generally possible to operate Francis turbines at loads within the range of their maximum efficiencies. The Peltons have the advantage when one unit of a power house has to serve as standby and to run at small load for long periods, or when, in run-of-the-river plants, the available discharge remains for long periods appreciably lower than the discharge required to run the turbine at half-load.

The speed of the Francis will always be higher than that of the Pelton, with corresponding reductions in the cost of the generators, and in the dimensions of the units, the machine hall and the power-house equipment.

In the paragraph concerning wear and maintenance we have seen that the efficiency of a Pelton is maintained in the neighbourhood of its original values at the cost of frequent overhauling and repairs. We have also given figures relating to the operation of high head Francis, which show that this type of turbine is beyond reproach in this connection.

The satisfactory operation of numerous high-head Francis runners has proved that this type of turbine is perfectly suited to heads ranging between 300 and 400 metres and the experience gained with these machines leaves us no doubt that the limits they have now attained will be appreciably increased in the future.

SEVERN BARRAGE

At question-time in the House of Commons recently, Sir Ian Fraser asked if, in view of the prospective shortage of electric power, His Majesty's Government would revive the Severn Barrage project.

Mr. Noel-Baker, the Minister of Fuel and Power, said that a Severn barrage could make no contribution to the supply of electricity during the next few years, since the work of construction might take eight years to complete. But the Government regarded the scheme as being of great interest, and arrangements were made some time ago to begin the preliminary work for the necessary model of the Severn estuary.

Sir Ian Fraser then inquired if, in view of the expected shortage of coal and the expected demand for electricity over many years, the Government would have a fresh study made of this and other means of getting electricity from other sources.

Mr. Noel-Baker agreed with the hon. member in thinking that the long-term importance of tidal power might be very great, but the first requirement was a tidal model of the Severn Estuary. After they had that, they could see what to do next.

During the course of a debate on Welsh affairs, Mr. Garner-Evans, the Member for Denbigh, said that there were vast schemes for hydro-electric development in Wales at present.

South-East Asia—Power or Poverty?

A special correspondent discusses the recently published report of the Commonwealth Consultative Committee on the development of south and south-east Asia.

"THE hydro-electric power resources (of south and south-east Asia) have hardly been tapped." This, in a phrase, is the conclusion of the Commonwealth Consultative Committee responsible for the report on the co-operative economic development of south and south-east Asia, known as "The Colombo Plan."

Four countries—India, Pakistan, Ceylon and Malaya—are the main states of the British Commonwealth examined in the Committee's report. In these and other areas of the Commonwealth total expenditure on fuel and power programmes over the six-year period covered by the report is put at £122 million, or rather more if certain of the multi-purpose projects associated with agriculture are included. But several other countries—Burma, Thailand, the associate states of Cambodia, Laos, Viet-Nam and Indonesia—are also within the scope of the wider plan, covering a vast area comprising about 570 million people, or a quarter of the world's population.

Rising Population

Population, indeed, is a prime consideration throughout the report and, as will be seen later, it is rising out of all proportion to the development of the quite considerable natural wealth available. In India, for example, the industrial expansion of the war years led to an increase in the output of electrical power which continued in the post-war years. Yet although today it is almost twice the pre-war level, it is still insufficient to meet the demands made upon it. With this and similar situations elsewhere it is quite understandable that the committee regard development as a matter of the utmost urgency, for, as they warn, "the longer the initiation of the necessary action is postponed the greater will the problem become. It brooks no delay."

Heavy Initial Cost

It is the early stages of the projects now in contemplation which are most costly and difficult, the report points out. Electricity, irrigation and other basic services require vast capital investment, but they must of necessity be undertaken before production—overall aim of the plan, and the touchstone for the safety and prosperity of south-east Asia as a whole—can be increased significantly. Pakistan, the subject of special articles in our last issue, is a case in point. The power potential of that country, now in dire need of new industry, is estimated at 5 million kW, yet the installed hydro-electric capacity is only 9,600 kW. Over the next six years it is planned to increase this by 200,000 kW, so that instead of Pakistan's per capita consumption being the lowest in the world for its 82 million inhabitants, every section of the community will benefit from the plans to be undertaken. The new access of power also will enable Pakistan to dispense with the supply of electricity at present imported from India, so that, as the committee warns, "in a country with such limited resources of oil and coal, hydro-electric power is of crucial importance."

700,000 kW Increase

In neighbouring India, there are three multi-purpose projects, all accorded high priority, and on which work already is in progress. They are the Damodar Valley (Rs.500 m. or £37.5 m.), the Hirakud (Rs.300 m., £22.5 m.), and the Bhakra Nangal (Rs.757 m., £56.8 m.). The last of these, involving the damming of the Sutlej, is designed to provide power for the cities of the north, including New Delhi, while the three schemes together are estimated to bring about 6 million additional acres of land under irrigation by 1956-7, and to increase electricity generating capacity by over 700,000 kW.

Electric power, it is constantly emphasised, is one of the three basic developments required to help in meeting the overriding need for increase in the output of food and agricultural raw materials. In India, Pakistan, and Ceylon this object will be achieved by projects which will combine irrigation, flood control and hydro-electric power.

Confronted with these and other essential works the virtual impossibility of individual countries financing their own schemes is underlined by the committee. So great is the need of economic development and so vast is the scale that the volume of investment necessary is far beyond indigenous resources. It is to be noted, however, that in Pakistan there are several undertakings in which Government and private enterprise work in partnership, the government being obliged to take the initiative in this way in order to inspire public confidence and to attract private capital. But it intends to withdraw its participation in these enterprises as soon as private capital is able to provide all the funds needed. In the general field of industry and commerce the dominant role in all countries is played by private enterprise, and in India it is anticipated that private enterprise investment will rise by about 60 per cent. over the six-year period of the report.

Anticipated Yield

Commonwealth results expected from the plan as at present outlined are:—

- 1.1 million kW electric generating capacity (increase of 67 per cent.).
- 13 million more acres of land under cultivation (increase of 3½ per cent.).
- 13 million more acres of land under irrigation (increase of 17 per cent.).
- 6 million more tons of food grains produced (increase of 10 per cent.).

The overpowering and paradoxical factor in the situation is that, despite all the potential wealth, the

(Continued on page 75)

Control of Hydro-Electric Plant

An abstract is given of a paper on this subject presented to the Institution of Electrical Engineers in London recently by A. C. H. Frost, B.Sc. (Eng.), A.M.I.E.E. and W. Brittlebank, B.Sc., A.M.I.E.E., of Messrs. Merz and McLellan.

THE authors first dealt with the various types of control used for hydro-electric plants, which they classified under the headings:

(1) *Manual Control,* whereby each item in the chain of the starting, synchronising, loading, and stopping sequence is selected and performed in turn by hand, whether mechanically or by push buttons.

(2) *Cottage-Attended Control,* with manual starting, etc., but running under supervision only of an alarm bell at the attendant's cottage.

(3) *Semi-Automatic Control,* whereby from a single manual starting impulse, a machine may be brought to the ready-to-synchronise condition automatically, synchronising and loading remaining manual functions.

(4) *Fully Automatic Control,* whereby a single starting impulse accomplishes the running up, automatic synchronising and connecting to the busbars and loading. Manual operation of loading and excitation may be provided as a remote control function.

(5) *Supervisory Control,* whereby telephone type apparatus, with the coded transmission of intelligence, is used for starting, stopping, and other functions initiated from a remote point.

(6) *Light Current Direct Control* as a variation of the preceding item, but where separate pilot wires are used.

They then gave a table of installations in which the various types of control are used, subsequently dealing with the basic types of turbine, and the main elements to be controlled. This part of the paper detailed the arrangements made for controlling the main water supply to the turbine casing; the runner-water admission and relief; the governor-servo system; the governor drive and speed and load setting; the lubrication systems; the generator-cooling systems; the braking and jacking systems of various miscellaneous equipment. Under each of these headings the authors gave a brief resumé of modern practice in regard to the devices used for each of the functions detailed above.

The power supplies to auxiliaries were next dealt with, and again the authors gave a brief paragraph to each of the possible methods of providing auxiliary supplies; these include the use of a station transformer and/or a house set; auxiliary supply from the main transformer circuits; and unit type auxiliary supplies, which the authors said are especially attractive for hydro-electric plants on account of the small number and size of the essential auxiliaries. The chief advantage of this scheme lies in that it minimises the amount of cable, switchgear, and transformer plant connected between the generator terminals and the associated auxiliaries. They said that an important simplification now in use comprises a scheme whereby the standby governor oil pump, which is usually driven by an impulse turbine, and the standby bearing oil pump, often battery driven, are used for starting, so that the essential auxiliaries can remain permanently switched to the unit transformer. As the generator gathers speed, the essential auxiliaries commence to rotate and automatically take over from the standby pumps, which then shut down. This method permits substantial saving in switchgear and also ensures that the standby plant is regularly subjected to a routine test.

Having thus described the elements of the control and auxiliary equipment in modern hydro-electric practice, the authors then proceeded to describe methods of control. They commenced by saying that manual mechanical control is becoming increasingly rare, except in the smaller stations, and that manual push-button control is taking its place with the use of motors remotely operated from the central control point.

They stated that cottage-attended control is practicable because hydro-electric stations can safely be left for long periods under the control of the turbine governors and automatic voltage regulators. If this method is adopted they feel it essential that comprehensive alarms should be provided, and in stations with more than one machine they suggested it is desirable to arrange for load-sensitive devices to sound the alarm when the load reaches the capacity of the running plant.

In dealing with semi- and fully-automatic control, the authors detailed the various methods which may be used, starting with the sequential system, in which the various mechanisms and auxiliaries are put into operation one after the other as each previous operation is proved complete.

They stated that the modification of the simple sequential scheme, known as the "sequential-parallel" system, has the advantage of combining simplicity of electrical equipment and circuits with minimum starting time. In this system the starting sequence commences with an impulse energising a master control relay, which remains latched-in whilst the machine is starting and running. This relay starts the standby lubricating and governor oil pumps, and at the same time initiates the opening of the main inlet valve, and starts a timing relay for an excessive-starting-time alarm. Thus the slowest operations involved in starting the machine are initiated to run in parallel in this first stage, thereby minimising the total starting time. Pressure switches and flow relays on the oil systems, and limit switches on the main inlet valve prove that the first stage is complete, and initiate the guide-vane (or nozzle) opening circuit, for the second

stage. If the simplified unit scheme for the auxiliaries, indicated above, is employed, the essential auxiliaries commence running as the machine gathers speed, and by virtue of pressure switches on their delivery lines, automatically shut down the standby pump.

The final stage in the "sequential-parallel" system involves the proof of delivery from the normal auxiliaries, coupled with operation of a voltage relay energised by the pilot exciter or the permanent magnet generator, when the machine is up to speed, which simultaneously energises a final-stage-signal relay and de-energises the excessive-starting-time relay. The final-stage-signal relay brings in the automatic synchronising equipment, in fully automatic stations, or transmits a signal "ready to synchronise" in semi-automatic stations.

The stopping sequence is similarly detailed, and the authors stated that control change-over facilities should be provided at the machine itself, so that the operations can be checked locally.

They went on briefly to describe various automatic synchronising systems, the main features of which are voltage matching, speed matching, and phase comparison relays.

Interlocking was dealt with, and it was shown that where semi- or fully-automatic control schemes are to be used, increased interlocking to check that the starting operations are carried out in the correct sequence, and that all auxiliary supplies and services are in order, is essential.

In dealing with electrical and mechanical protection, the authors outlined the conventional protective gear apparatus needed, but mentioned that there is considerable divergence of view as to the treatment of emergency shutting down. They advocated a scheme whereby all main protective devices should operate one hand-reset relay. Separate contacts of this relay should trip the main switch, open the field switch, close the main inlet valve, close the guide vanes or nozzles, and apply the brakes; and, in automatic schemes, the relay should also restore the master control relay. These circuits should be arranged so as to override all hand automatic controls.

The next sections of the paper described apparatus which is available for control purposes, such as valve position indicators; pressure and flow-detection device; speed and temperature sensitive devices; and alarm display equipment.

An interesting feature of the paper is Table I, reproduced herewith, which shows a cost comparison for a hypothetical group, comprising five two-machine power stations and one main substation, covering ten miles, with group control administered from the substation site.

This Table related particularly to the penultimate section of the paper, which dealt with group control. The authors stated that the establishment of group control centres are a comparatively new conception. Where topography favours the development of a river system in several steps, as among the changeable slopes of our national uplands, the resulting chain of power stations may be controlled from a single point which may be the one major high-voltage substation.

The group centre will require an indication of each machine load, from which to derive automatically or statistically the total load on each power station, and hence the total load on the group. Chart records for both group and station total load will be required. The hydraulic information needed will relate to reservoir levels and tailrace levels, when these are subject to large fluctuations, and the authors suggested that special rain gauges at representative points in the catchment area should be developed, in conjunction with simple automatic radio transmitters for inaccessible gauge sites to signal, say, after every 0·1 in. of rain has collected.

On the subject of communication, the authors suggested that power-line carrier systems provide as good or better quality with comparable reliability and many more channels, than open wire and other pilot lines.

In the concluding section, dealing with the choice of control schemes, the authors stated that the manual mechanical system is only adequate if operating staff are available in sufficient numbers and ability. Cottage-attended schemes are limited to the rare cases of small isolated systems, while when starting time is important the effect of the human element renders fully automatic control a close second.

In view of the fact that hydro-electric stations are perforce generally located in isolated regions in which it is difficult to persuade operating staff to reside, there is obviously a greater tendency to use the maximum degree of automatic control. The overall economic advantage is demonstrated in the figures given in Table I.

In the discussion, Mr. T. G. N. Haldane (Merz & McLellan) spoke first, and said that the paper focused attention on the inherent controllability of hydro-electric plant. The control of such plant was very much less complicated than that of steam plant of an equivalent output. Further, many hydro-electric schemes enabled full load output to be achieved in less than five minutes. In view of these qualities, Mr. Haldane suggested that it was only by using remote control facilities that best advantage could be taken of water power. If water-power plants could be brought on load quickly and controlled flexibly and economically, it followed also that the thermal plant connected to the same system could be operated in a more economic fashion.

The next speaker was Mr. A. R. Cooper (Divisional Controller, Merseyside and North Wales Division,

TABLE I

Method of Control	Cost, in Thousands of Pounds.				
	Number of Operating and Maintenance Staff required for the group	Turbine Control Equipment, Compressor Plant and Cables	Salaries (15 years' capitalisation on an average of £450 p.a.)	Staff Houses at £1,500 each	Total for Plant. Salaries and Houses
Local manual	120	56	810	180	1046
Local semi-automatic .	95	86	642	143	871
Remote semi-automatic	45	105	304	68	477
Remote fully-automatic	45	110	304	68	482

British Electricity Authority) whose remarks principally concerned the problems of staffing remote hydro-electric stations. He said that these problems were not entirely technical; the case as to whether or not automatic control should be installed might well be decided by the difficulty of finding the few technical operatives who would be necessary to maintain such schemes, and who would be prepared to live under conditions of social isolation. Mr. Cooper also mentioned that, in his opinion, unit type of auxiliary plant layout was preferable.

Mr. A. T. Mitchell (Boving and Company) said that the governor oil system was the vital point in turbine control, and he stressed the necessity for maintenance of oil pressure under emergency conditions. Air must not be drawn into the governor in any circumstances, as it might cause pipeline trouble. He described a method of checking the oil level in the governor air/oil reservoir by means of an internal float which operated an external oil level device by magnetic means. He said that it was essential to maintain governor oil pressure during shut-down periods. He also dealt with the question of auxiliaries and said that he favoured the provision of a house turbine. His final point concerned a query as to whether limit switches should be provided on the speeder gear, when automatic synchronising was used.

The next speaker was Mr. F. H. Williams (British Electricity Authority, in charge of the Galloway hydro-electric scheme). He stated that on the Galloway stations it was possible to bring 24,000 kW of plant on load in three minutes, by manual control and synchronising. Automatic stations were not so quick, as, for instance, filling pipelines took twelve minutes. Automatic synchronising was not so rapid as manual synchronising.

Mr. Williams mentioned that he preferred gear driven governor drives, as with this method there had been absolutely no trouble during many years of service, and he was surprised that the authors felt that electrical governor drives were advantageous — the fewer the electrical "gadgets" the better. In the damp atmosphere of many hydro stations, the electrical insulation of secondary apparatus was liable to suffer. Mr. Williams felt that a Pelton wheel oil pump for the main lubrication system is ideal, and he also said that the 250 volt pressure for the D.C. battery and D.C. auxiliary supply system, mentioned by the authors, was not necessary. In his opinion a 110 volt system was quite sufficient. He could not agree that automatic controlled stations did not need any attendants at all. There had been occasions when rapid deterioration in weather conditions had caused flooding in the power station, and if an attendant had not been present the results might have been disastrous.

Mr. E. M. Johnson (Metropolitan Vickers Electrical Company) said that he felt the schemes used by the authors to illustrate their arguments, were not really typical, and that the very large number of different conditions under which hydro-electric schemes operated meant that little generalisation was possible.

Mr. B. Donkin (Kennedy and Donkin) said that negative phase sequence protection should be employed for hydro-electric generators. He also pointed out that the authors had not mentioned the problems of bringing indications back from distant headworks. Unless the greatest care was taken to ensure that the telephone lines or pilot cables were invulnerable to climatic conditions, there was a distinct danger that they might be out of action when required in an emergency.

Mr. A. C. H. Frost briefly replied, pointing out that many of the points raised related to hydro-electric power station design rather than to the specific subject of the paper, which was the control of hydro-electric plant. He promised that detailed answers would be given in the Institution's Journal.

A Brochure on Génissiat

Our esteemed French contemporary, *La Houille Blanche*, in collaboration with la Compagnie Nationale du Rhône, has just published a special brochure devoted to the Génissiat hydro-electric installation, regarded as the chef-d'oeuvre of French engineering. It is a beautifully produced volume of 296 pages, carrying 225 illustrations, and constitutes a complete record of a remarkable piece of work which represents a milestone in French hydro-electric development. The following is a summary of the contents:—

"Regulations, Past and Present, of la Compagnie Nationale du Rhône," by G. Tournier.

The Conception of Génissiat

"Elaboration of the Project," by M. Henry; "Geological Conditions governing the Hydro-electric Development of the Rhône between Geneva and Seyssol," by M. Gignoux and J. Mathian.

Civil Engineering

"A Conspectus of the Civil Engineering of Génissiat," by G. Gres; "Preliminary Work on the Génissiat Dam," by Ch. Chagnaud; "Main Constructional Work," by H. Escalon and H. Diserens.

Equipment

"Hydro-Electric and Mechanical Equipment of the Léon-Perrier Central Station at Génissiat," by A. Robert; "The Génissiat Penstocks," by G. Ferrand; "The Turbine Butterfly Valves," by L. Armanet; "Some Problems presented by the Design and Construction of the Génissiat Turbines," by J. Arnoud and A. Suss; "The Génissiat Sluices," by H. Gerodolle and F. Mussard; "The Génissiat Development and the Future Exploitation of the Rhône," by P. Delattre.

This brochure, which, of course, is in French, is available from *La Houille Blanche*, Boite Postale 41, Grenoble, Isère, at 1,400 fr. in paper covers or 2,100 fr. as a bound volume.

SOUTH-EAST ASIA: *from page 72*

fundamental problem of the entire area is poverty. According to official sources the population of the area is growing by something like 20,000 a day, but agricultural productivity is low and industrial power has not developed to an extent which can meet even barely the growing masses or improve their standard of living. This is a serious matter, for apart from the low economic standard of the people the existing poverty tends to cloud and circumscribe the human assets which the area possesses. The first and foremost aim of the plan is to relieve those conditions.

In this vital respect the committee sums up realistically. "The programmes" it says "will do little more than hold the present position, but it will be apparent to everyone in south and south-east Asia that progress is being made. The strength of these programmes is that they are designed to lay sound foundations for further development. They aim to provide, in a six-year period, the indispensable preliminary basic development which will pave the way for improvement."

Tiltman Langley Flow Valve

AT the invitation of Tiltman Langley Laboratories Limited we attended a demonstration of a new valve which they have devised and which can easily be arranged for remote control by a small energy impulse created by electric, hydraulic or pneumatic means. It provides a perfect seal—there are no glands—and the general design is such as to lend itself to construction in non-corrodable materials. It is claimed that closure and opening can be arranged to be instantaneous or as gradual as desired. A diagrammatic cross-section of the valve is given in Fig. 1. The housing contains a central cylindrical body, *a*, with rounded ends supported by three radial webs. At the inflow end a central supply hole is bored and communicates with a piston chamber at the outlet end, the lateral movement of the round-ended piston opening and closing the discharge orifice. Connecting the piston chamber to outlet side of the valve is a bypass channel *d*. When this bypass is closed a pressure is built up against the piston in excess of the flow pressure acting on the downstream end; in consequence the piston component is pushed towards the valve seating (Fig. 2) and the discharge orifice is closed. The piston continues to be held in the closed position in virtue of the pressure on the loaded area, indicated by arrows, and is of course discernibly greater than the opposing pressure exerted on the rounded end. It is the difference between these pressures that forms the effective sealing force.

On opening the bypass, the pressure on the piston is relieved, being dissipated more rapidly than it can be built up through the fine supply hole *b*. The load on the upstream face of the piston thus becomes negative compared with the pressure on the rounded downstream face and the component moves back, Fig. 3, opening the orifice to the full flow of the fluid. By adjusting the size of the orifice *b* the rate of operation in any set conditions can be controlled to a nicety so that water-hammer effects can be obviated. Furthermore by controlling the rate of flow through the bypass by means, say, of a needle valve, the pressure in the bypass can be balanced against the pressure induced through the small orifice *b* and a minute movement of the piston induced in either direction; the rate of the main flow can be varied with a minimum of frictional loss. The shape of the inlet and outlet ends of the valves is important in this respect and the shape of the body is also conducive to low frictional losses because the clearance can be calculated to avoid instability.

The model demonstrated was of about 1 in. pipe bore and worked with admirable precision and it would seem that the construction of valves of the largest size, designed to deal with high pressure, need present no insuperable difficulty. Such at any

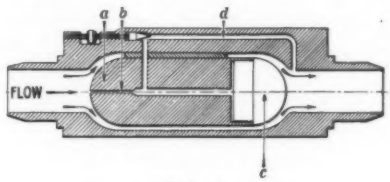


Fig. 1

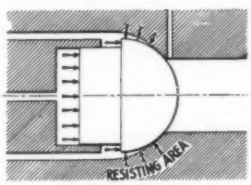


Fig. 2

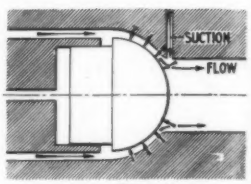
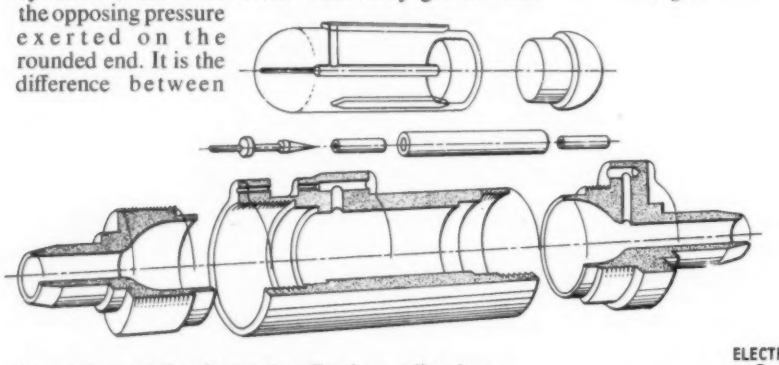
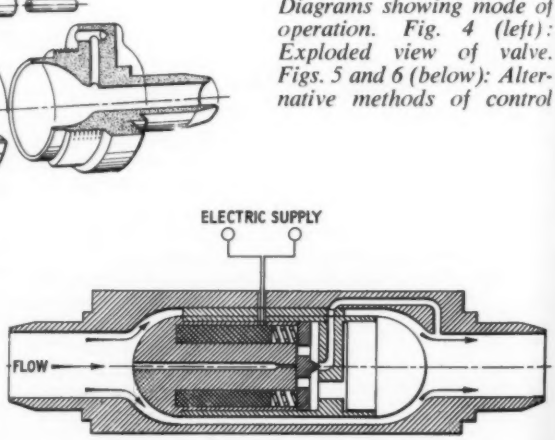


Fig. 3



Figs. 1, 2 and 3 (above): Diagrams showing mode of operation. Fig. 4 (left): Exploded view of valve. Figs. 5 and 6 (below): Alternative methods of control



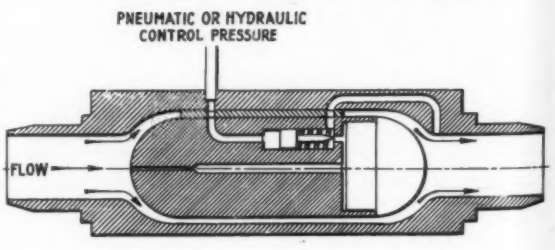
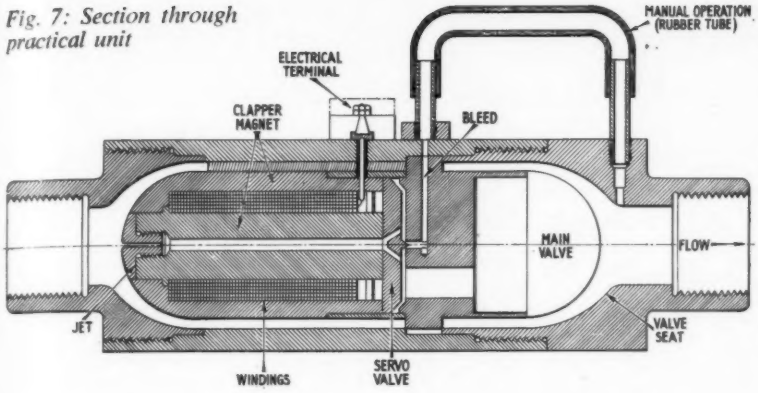


Fig. 7: Section through practical unit



rate was the opinion of the inventors who are open to accept offers for manufacturing rights.

Figs. 5 and 6 show the arrangements for operating the valve by electrical means and by hydraulic or pneumatic pressure, and Fig. 7 shows the construction of a practical-scale unit. Easy accessibility is claimed; removal of the outlet connection enables both the piston and central body to be removed. No fine tolerances would appear to be needed, the piston and bore requiring only a normal sliding fit, and no sealing rings are necessary. In practice a greater clearance between the piston and the shoulder is allowed near the shoulder end and the sliding fit confined to the face only. This enables the rounded end to align itself perfectly against the outlet wall of the valve, where, if necessary, a rubber sealing ring can be inserted. For other applications the piston is ground in with the seat to ensure positive rating.

Remote control can readily be secured. The bypass itself may be extended to some 15 ft. and its pressure-releasing ability controlled by a simple "on" and "off" cock. For a greater distance electrical, pneumatic or hydraulic control is recommended. With high accelerations of the fluid flow certain precautions are necessary; to meet such requirements the piston is made either completely or partially buoyant in the fluid and will then operate with high accelerations applied from either direction.

It should perhaps be mentioned that the valve was originally designed for fuelling aircraft where a glandless valve offered an ideal safety feature against leakage and incidental risk of fire. But it has other obvious advantages and it is proposed to grant manufacturing licences to firms who wish to apply the design to any particular industry.

New "Vickers" Rolls-Royce Engined Tractor

A NEW heavy-type Class I tractor designed for industrial earth moving purposes is to be put on the market by Vickers Limited and will be manufactured at the Vickers-Armstrong works at Elswick and Scotswood on the Tyne. It will be known as the "Vickers" tractor and it is claimed that the many new developments which have been incorporated in the design will make it suitable for wide use throughout the world. It will weigh between 14 and 15 tons and will be driven by a 180 h.p. Rolls-Royce diesel engine. The reputation enjoyed by both the participating companies is sufficient to assure the highest standards of workmanship and design, but to make this assurance doubly sure the prototype models, which have been undergoing development for three years, have been submitted to the severest of tests over a period of twelve months. It is estimated that over £1,000,000 has been spent on research and development, this being an indication of the importance attached to the production of a British machine of this type.

Prototype of the new Vickers tractor driven by a 180 h.p. Rolls-Royce diesel engine

Prototype machines will be made available to operators for practical-scale field trials during 1951 but full production will not begin until 1952 when it is planned to work up to a production rate of 500 machines a year.

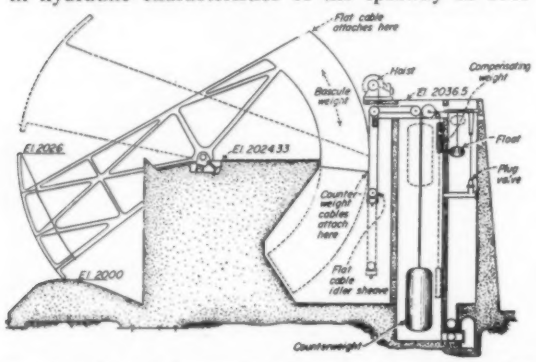
Arrangements have been made with Jack Olding & Co. Ltd. to be the distributors throughout the world and to provide facilities for spares and servicing. It is claimed that this development represents the largest project in heavy tractor production that has ever been undertaken in this country.

Oil Seals.—Charles Weston & Co. Ltd. have issued a catalogue on their oil seals in which almost innumerable types are illustrated and described. Information is given on installation, and dimensions are given in both inches and millimetres.

From the Journals of the technical institutions and other material published in the Press of the World

Horseshoe Dam Radial Gates

The Horseshoe Dam on the Verde River, 50 miles from Phoenix, Arizona, is equipped with three radial gates which combine the record size of 114 × 26 ft. with automatic working, and present other features of an uncommon character. For instance, the supporting piers are located behind and within the span of each gate. This achieves an important improvement in hydraulic characteristics of the spillway as compared with end-supported gates. It also permits the gates to be continuous across the ogee spillway crest, and as the automatic control makes all three gates operate simultaneously, the result, in effect, is a single gate 342 ft. wide.



Each gate is supported by trunnions mounted on a pair of piers located about one-fifth the gate span from the ends of the gate. Bascule weights designed to counterbalance the gates are mounted on the downstream ends of the gate arms, and descend into wells in the piers as the gates open.

Gate operation is controlled automatically by the level of the water in the reservoir; the gates may be operated by means of electric hoists, however, when necessary. Further, if required, each gate can be operated separately, although all three will normally work together.

When the operating wells in the pier are dry, the counterweights act, in contrast to the bascule weights, to hold the gates in a closed position. As water rises in the reservoir, it flows into the counterweight wells, thus reducing the effective weight. The radial gates will be raised and lowered automatically by varying this effective weight so as to balance the moments of the dead loads and the hydrostatic forces on the gate faces. Water from the reservoir flows through a 24-in. feeder pipe to risers in each pier, and fills to the same level as the reservoir float chambers connected with the counterweight wells by means of an outlet controlled by a needle-type valve. As the reservoir continues to rise, water admitted through this valve into the counterweight chambers will rise and continue to reduce the effective weight of the counterweights. An 18-in. diameter pipe interconnects each pair of counterweight chambers, so as to maintain equal level in these chambers for each gate.

The gate will open whenever the closing force and seal friction are overcome by the reduction in effective weight of the counterweights. By varying the inflow of water to the counterweight chambers, and maintaining therein predetermined water levels, movements of the gate are controlled automatically. For each reservoir level there is a corresponding gate opening at which all forces are in balance.

One end of the cable supporting the sheave from which the plug on the needle-type valve is hung runs to a float in the float chamber, the other end being attached to a drum on a sprocket wheel that turns as the counterweight and the radial gate move. Any rise in reservoir will cause the float to rise and slacken the cable, and thereby cause the plug in the outlet valve to open. Conversely, any opening movement of the radial gate will cause the plug to be lifted, tending to close the outlet from the float well into the counterweight chamber.

Each counterweight chamber is provided with a restricted drain that remains open at all times so that some water must be admitted to the counterweight chambers through the needle-type valve to maintain water depth in that chamber. Consequently, for any stage of the reservoir there is only one gate position at which flow through the needle valve will exactly balance the outflow from the counterweight well.—*Engineering News-Record*, Vol. 145, No. 11, September 14, 1950, p. 44, 2 pp., 3 ff.

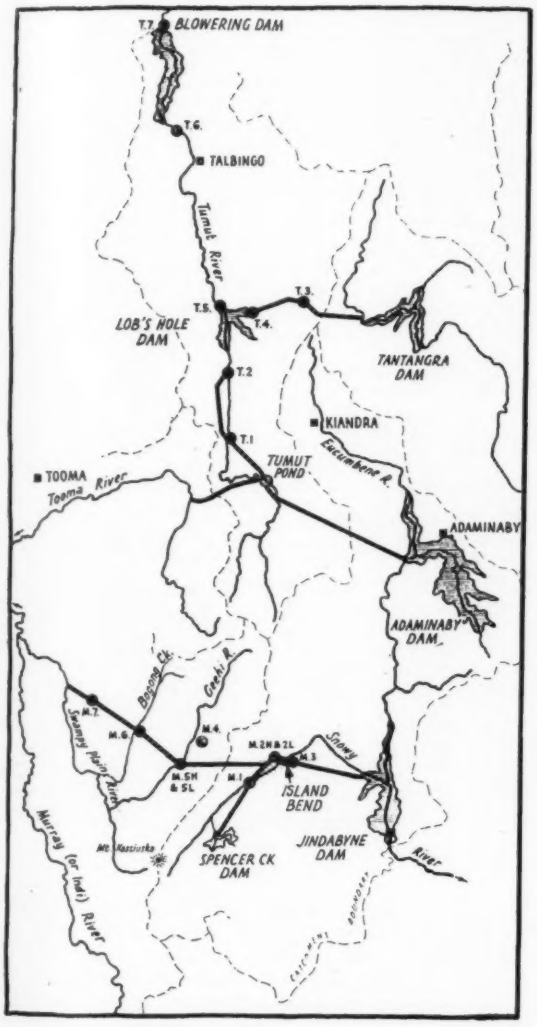
Snowy River Scheme

In our issue of May-June 1949, Vol. 1, No. 3, p. 101, we discussed the principal recommendations contained in the report submitted to the Federal Australian Government on the Snowy River Scheme. The following is a summary of an address delivered last summer to the Sydney Division of the Australian Institute of Management by Mr. W. Hudson, Commissioner of the Snowy Mountains Hydro-Electric Authority. The address, which begins with an interesting historical survey of the scheme, shows the remarkable progress achieved since the establishment of the Authority.

The winter snows which cover the Snowy Mountains, Mr. Hudson stated, constitute a huge natural reservoir which releases its water just during the period it is most needed under the influence of the summer sun. From the four rivers flowing from this area, viz. the Murrumbidgee and the Tumut, its tributary, the Murray and the Snowy, it is the Snowy which receives the greatest portion of the run-off;

these waters, which hitherto flowed to waste through the north-east corner of Victoria, are being harnessed for a double purpose; after being used for the generation of electricity, they will join the Murray and Murrumbidgee systems for use in the irrigation areas of the west. The whole scheme is thus divided into two sections, known respectively as the Snowy-Murray System and the Snowy-Tumut System. (See sketch map.)

In the former system, a tunnel 35 miles long will



divert from the Jindabyne reservoir the whole of the Snowy River, with the exception of the waters of the Eucumbene tributary, to the Swampy Plains River in the Murray Valley, 2,000 ft. lower on the other side of the mountains. Parts of this tunnel, which will vary in diameter from over 30 ft. to 45 ft., will be 3,000 ft. underground; it will be fed with additional water from the Upper Snowy at Island Bend through a shaft 1,000 ft. deep, and more water will flow into the main tunnel where it passes under the gorges of the Geehi and Bogong, both tributaries of the Murray. There will be power houses at Bogong Creek (M.6), and at the tunnel outlet at Swampy Plain, as well as at the points where water is fed into the tunnel. In addition, the waters of the Upper Snowy will be caught up at an elevation of nearly 6,000 ft., a few miles from its source on Mount Kosciusko, and dropped from the 1,000 ft. shaft at Island Bend into the tunnel after passing through a series of power stations (M.1, M.2, and M.3).

In the Snowy-Tumut System, the Eucumbene will cease to flow into the Snowy River, and its waters will be diverted partly into the Murray, partly into the Tumut, a tributary of the Murrumbidgee.

A dam will be built on the Eucumbene near Adaminaby, and a tunnel driven under the ranges to Tumut Pond on the Upper Tumut. This tunnel, about 35 ft. in diam., will have an approximate length of 15 miles. At Tumut Pond the water from the Eucumbene will be supplemented by the flow of the Tumut River plus water diverted through another tunnel from the Tooma, a tributary of the Murray. The relative levels of the two tunnels will permit, when required, to reverse the flow in the Eucumbene tunnel, and to turn the surplus water from the Tooma into the Adaminaby Reservoir for storage.

The combined waters of the Eucumbene, Tooma and Upper Tumut, collected at Tumut Pond, will flow through a 5-mile tunnel to a power station (T.1) on the banks of the Tumut; down the Tumut Valley there will be four additional power plants. Power will further be developed by diverting water from the Murrumbidgee near its source (Tantangra dam) through a tunnel into the Tumut at Lobbs Hole.

The whole scheme involves the following construction work: seven major dams, 87 miles of tunnelling, 16 power plants, and almost 500 miles of channels cut into the mountain sides to gather streams at high elevation. The power produced, 2,750,000 kW, will exceed the total capacity of all stations, thermal or hydro-electric, now in operation in Australia, while no less than 2,000,000 ac. ft. of additional irrigation water will be available.

Work in the field started at the beginning of December, 1949; the number of employees has already passed the 1,000 mark, and the construction of the Authority's headquarters township at Cooma, and one of the works townships at Jindabyne is going ahead actively. Workmen's camps have been established at various spots, and the opening up of roads into the working points in the mountains and gorges is in progress. It is hoped that the first power producing centre (60,000 kW) will be in commission at Island Bend within five years. — *W. Hudson, Commonwealth Engineer,* Vol. 38, No. 1, August 1, 1950, p. 17, 7 pp., 5 ff.).

The French Rhône Scheme

The importance of the Rhône as a source of power —apart from the possibilities in regard to navigation and irrigation — was recognised and discussed long before May 1921, at which time the French Parliament passed an Act to bring the whole of the work connected with the scheme within the orbit of a single concession. Thirteen years were to elapse before this concession was granted to the " Compagnie Nationale du Rhône " (C.N.R.) and from that time on things moved much more quickly; the general plan of power

and navigation development worked out by the C.N.R. now comprises the following:—

Upper Rhône: ten power plants with an aggregate output of 3,000 m. kWh per annum (the Cusset-Jonage plant, upstream from Lyons, existed before the setting up of the C.N.R.);

Lower Rhône: eleven power plants with an aggregate output of 10,000 m. kWh per annum.

Work completed, in progress or about to be undertaken by the C.N.R. covers a number of navigational

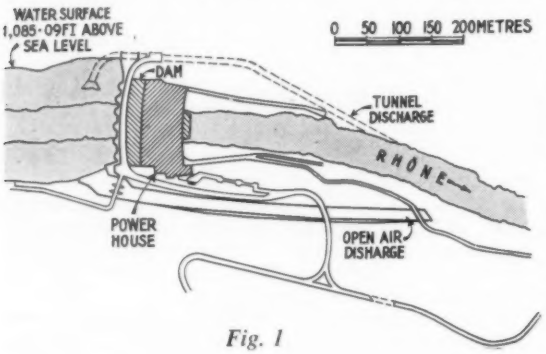


Fig. 1

improvements near Lyons and the Lower Rhône, those sections of the river which, from the aspect of power generation, are the most important. These include Génissiat, on the Upper Rhône, at which there is a gross head of 266.28 ft., and which was put into operation in 1947; Seyssel, 27.88 ft., in course of construction; and Sault-Brénaz, 30.50 ft., work on which is scheduled to start in 1951. On the Lower Rhône the schemes include Donzère-Mondragon, 85.30 ft. head, in course of construction; and Montelimar, 59 ft., work on which is to begin in 1952.

Priority in the whole scheme was given to the Génissiat dam and plant because it was at this spot, about 14.5 miles from the Swiss border, that the French Rhône reaches its steepest natural slope. Work on this section was begun in 1937, but was of course delayed by the war. Here an open-cut excavation of 850,200 cu. yards was carried out under the protection of two cofferdams, the water being diverted by means of tunnels, one on each bank, 1,968 ft. in length, having a cross sectional area of 101.66 sq. yards. Alluvium to a depth of nearly 100 ft. had to be removed from the river bed before foundation rock (limestone) was encountered for the dam, which is of arched gravity type and has the following characteristics: radius of arch in the horizontal plane, 1,640 ft.; height above foundations, 340.2 ft.; volume of concrete, 575,520 cu. yards; height of crest above sea level about 1,100 ft.

The storage reservoir formed by the dam has an area of about 865 acres, and extends as far as the Swiss border.

Flood water discharge is provided for by an open-air channel on the right bank, and a tunnel on the left bank. The power house is incorporated in the dam and is fed by six 18.86 ft. dia. penstocks, of which five are now in operation. The maximum water delivery is 20,000 cusecs., and the possible yearly output 1,600 m. kWh, for an installed capacity of 325,000 kW. The five vertical-shaft turbo-alternators in operation have the following characteristics: gross head at power house, 196.85 to 226.38 ft.; Francis turbine, maximum power 100,000 h.p., 150 r.p.m.; three-phase alternator, 15,000 V., 50 cycles, 65,000 kW; total load on thrust bearing, 768 tons; transformers, ratio 15,000/220,000. Two auxiliary 2,500 h.p. sets, driven by Francis turbines, are also available.

Five miles downstream from Génissiat, work is in progress on the Seyssel dam and power house, the latter to be equipped with three 20,000 h.p. sets for an output of 200 m. kWh per annum.

The prominent part played in the Upper Rhône development by the Génissiat plant will be paralleled on the Lower Rhône by the Donzère-Mondragon installations. This section of the Rhône lies between its two tributaries, the Isère and the Ardèche, and presents a particularly steep slope (0.075) which the C.N.R. are anxious to utilise at the earliest possible moment. Work on these projects was begun in 1948.

The Donzère dam will raise the level of the Rhône by 16.40 to 19.68 ft., and in addition a canal will be provided for navigation purposes, divided into six sections, one 150 ft. wide and five 103 ft. wide. Headwater control is ensured in all six sections by crest gates of the sector type, about 30 ft. in height.

The turbines are designed to accommodate a delivery of 54,000 cusecs. at a head ranging between 52.50 and

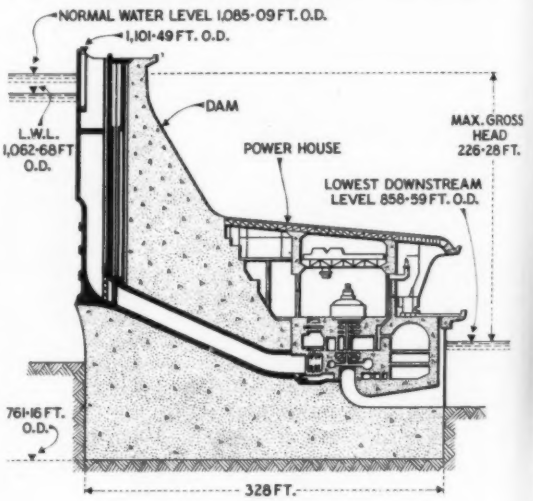


Fig. 2

85.31 ft. When completed this plant will have six vertical-shaft generating sets having a capacity of 300,000 kW, with an average output of 2,000 kWh per annum. Four of these sets are now on order, each having the following characteristics: adjustable-blade propeller runner absorbing about 9,000 cusecs. giving 70,000 h.p. (max.) at 107 r.p.m., the alternators being rated at 50,000 kW at 10,500 V. The thrust bearing, mounted on the lower bridge of the alternator, will support a load of 1,400 tons.

The volume of earth and rock to be excavated in connection with the Donzère-Mondragon plant is assessed at 65.4 m. cu. yards and the aggregate volume of concrete required at about 497,040 cu. yards. It is expected that the first set will be put into operation at the beginning of 1952. — *A. Jacard, "Wasserund Energiewirtschaft,"* Vol. 42, No. 8, August 1950, p. 121, 5 pp., 8 ff.

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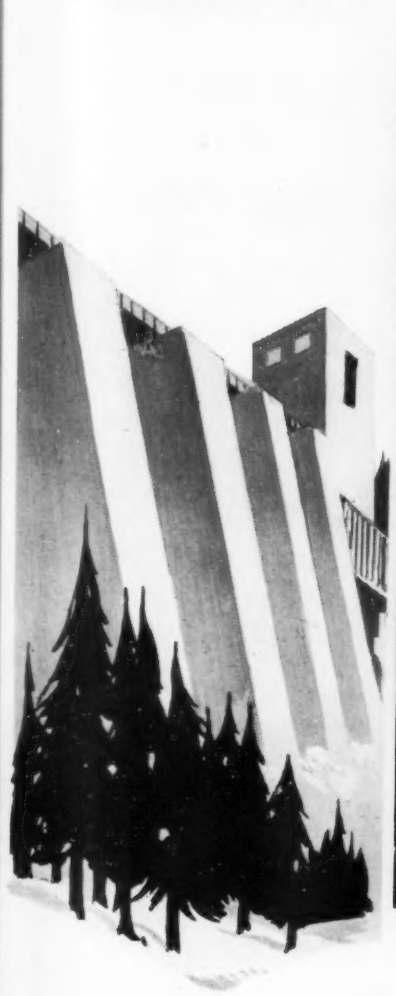

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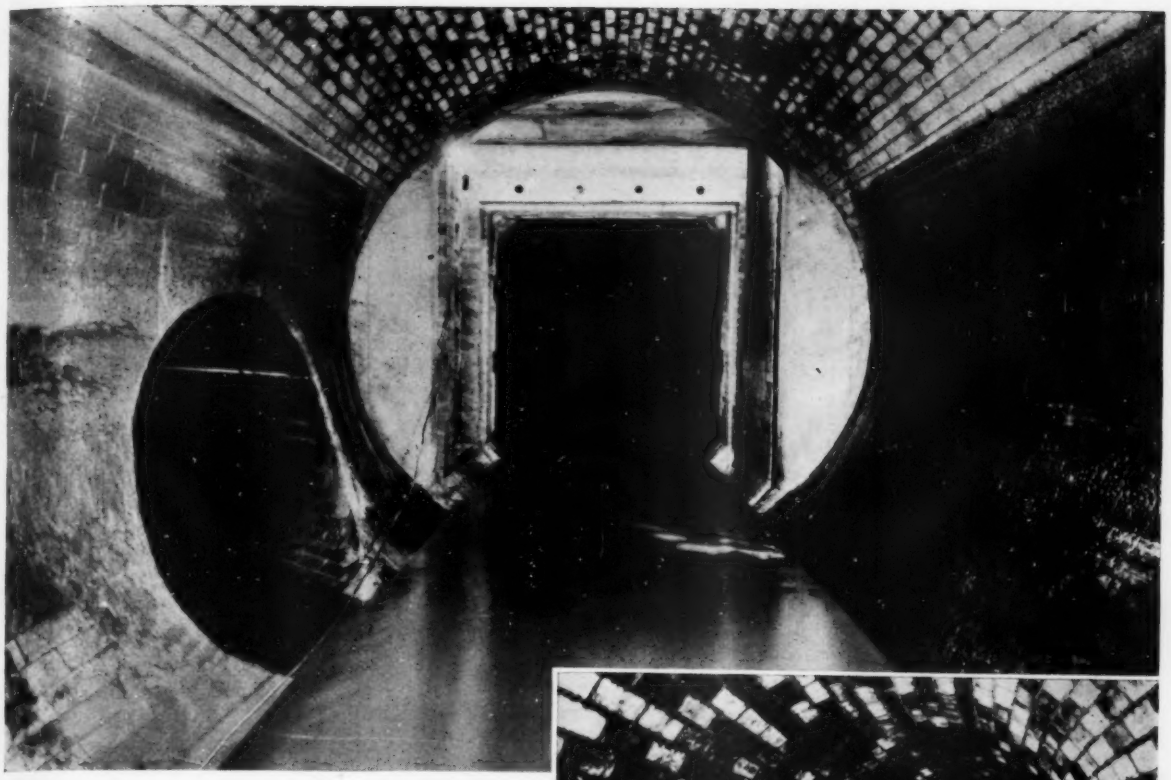
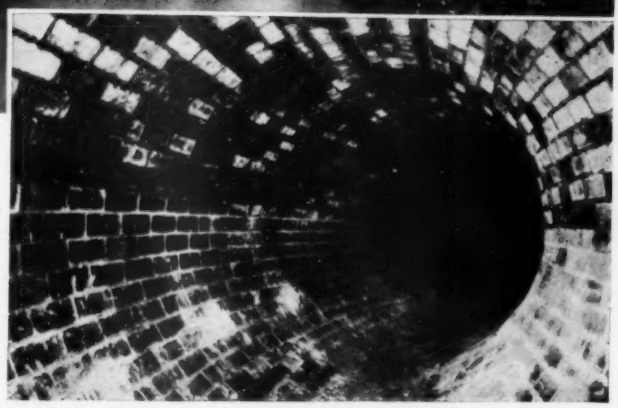


ABOVE: *Completed 10 foot Penstock Chamber looking downstream*

RIGHT: *Curve at upstream end of new sewer*



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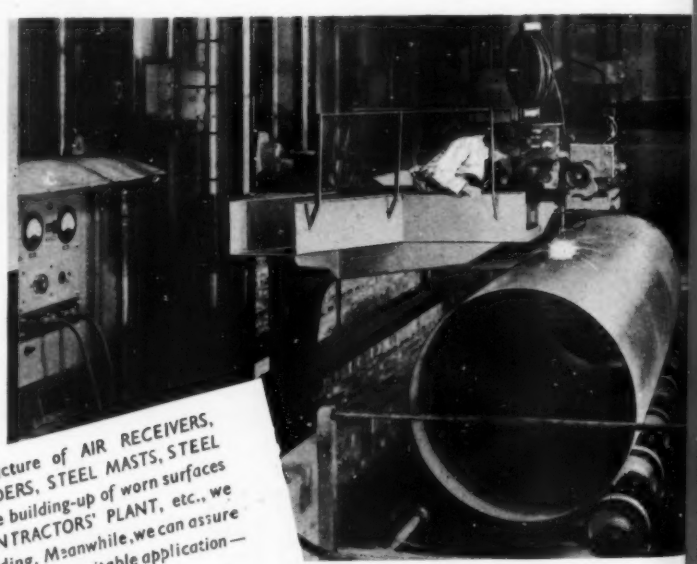

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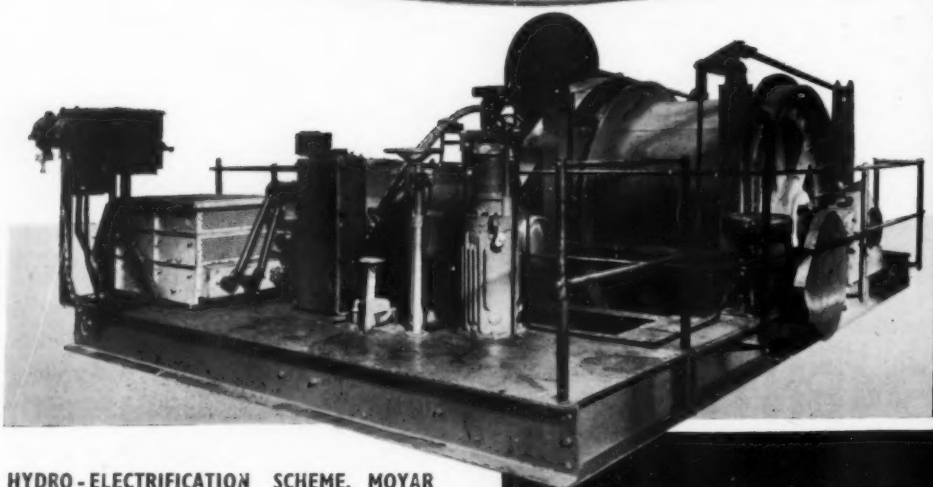

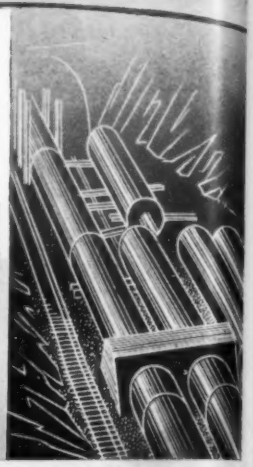

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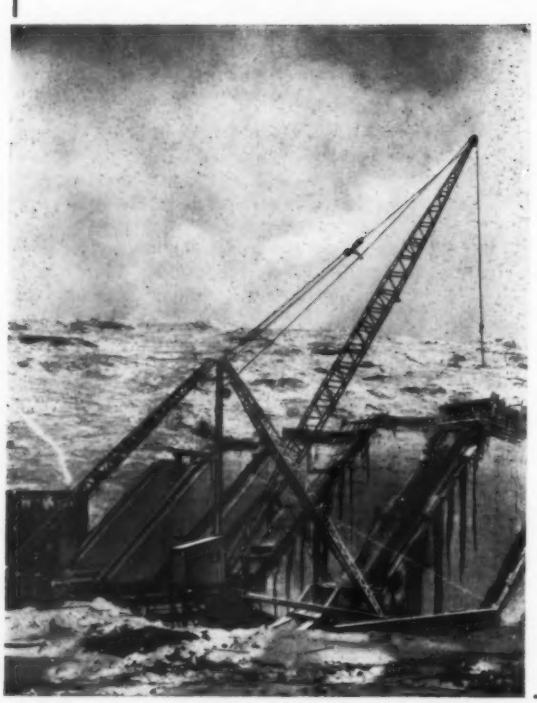

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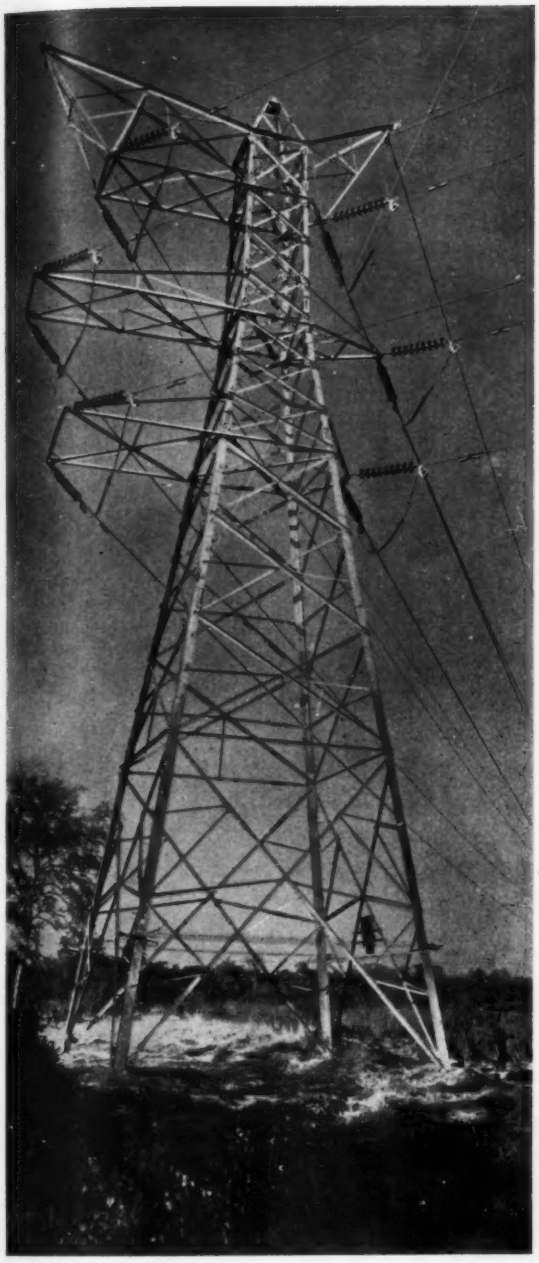

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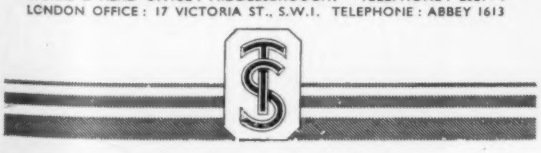

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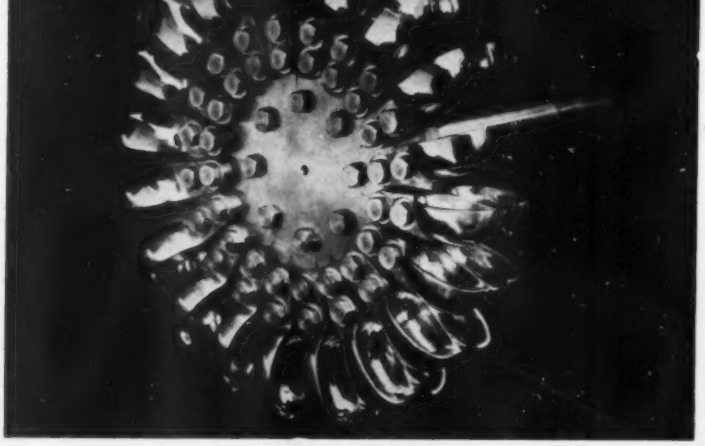

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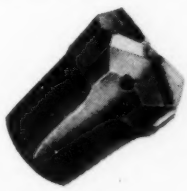

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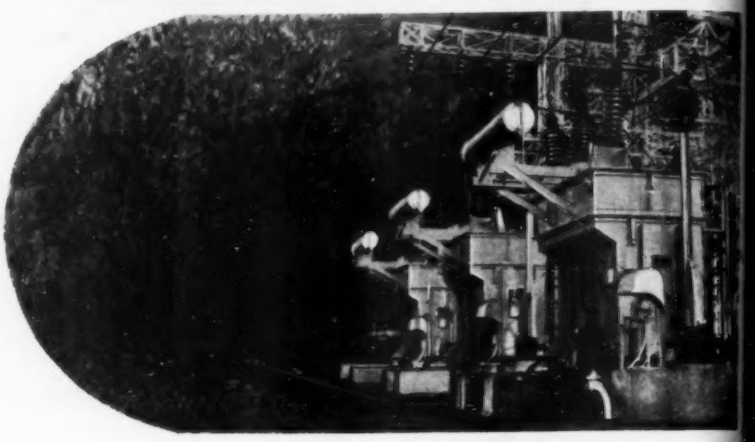

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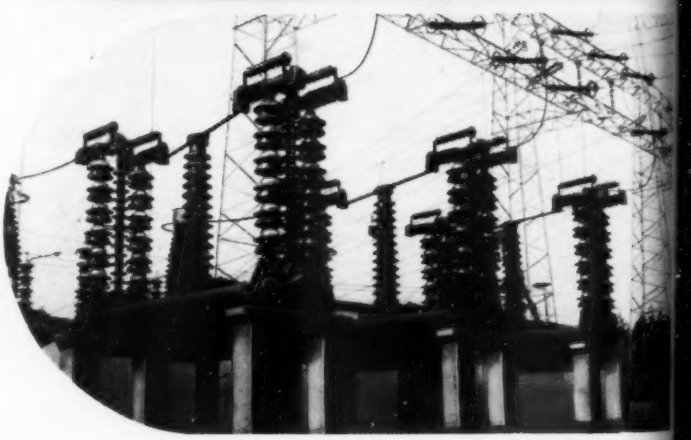

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